Mechanical Engineering of Collieries.

C. M. PERCY

Sincerely Yours
C. M. Percy.

THE

MECHANICAL ENGINEERING OF COLLIERIES

BY

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MINING AND MECHANICAL SCHOOL. WIGAN.

(*See Appendix, page 214.*)

VOLUME I.

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TO

ALFRED HEWLETT, Esq.,

OF

HASELEY MANOR, WARWICK,

THIS WORK IS

DEDICATED

AS A HUMBLE TRIBUTE TO HIS EMINENCE
IN THE MINING WORLD, AND
IN REMEMBRANCE OF TWENTY HAPPY YEARS SPENT
IN HIS EMPLOY,

BY HIS FAITHFUL SERVANT,

THE AUTHOR.

PREFACE TO THE FIRST EDITION.

A DISTINGUISHED man of letters of the last century, Horace Walpole, is credited with having said that "any one who would write about what he knew, and write in simple language, would produce an interesting book." To such a man as Walpole, with high literary capabilities, and revelling in all the pleasures that came so easily and in such abundance from the valuable sinecures of "Usher of the Exchequer," "Comptroller of the Pipe," and "Clerk of the Estreats," book writing may have formed an enjoyable pastime at different periods of his luxurious life. It is not so with many who in this more busy and practical day have less aptitude for literary work, and whose lives are not so much times of ease and indulgence as was the case with Horace Walpole. I candidly confess that having written for the most part about what has been my constant occupation for twenty years, and having tried to write so simply as to run the risk in some quarters of eliciting something approaching contempt, I feel that all my efforts have failed to produce what I had endeavoured and hoped, an instructive and interesting book.

There has been abundant scope, and there has been no want of will, but there has been lack of capability, which perhaps the reader will consider rather a misfortune than a fault.

That this book should have been written at all requires a word of explanation.

Engaged, boy and man, since 1860 amidst the extensive iron works and collieries of the Midland Counties and the North, I have experienced the want of some practically written and not too extensive work, dealing with the mechanical engineering of these important industries.

Called in 1868 to the evening lectureship on engineering at the Wigan Mining and Mechanical School (which, established twenty-five years ago, has for several years had upon its books a large number of students each session, drawn from a wide district, and is just entering into

possession of rooms which, although only considered temporary, have cost for erection and equipment several thousand pounds), the years that have since elapsed have shown me more and more the need of such a text-book for students and guide for practical men.

Mining literature is not extensive, and practically comprises a few large and expensive productions and the *Transactions* of the various mining institutes. The former are ponderous volumes, dealing for the most part with mining pure and simple, and the latter are confined to members, who are hardly the class of persons most in need of instruction.

Towards the end of 1879 a sad case of overwinding resulted in the loss of several lives, and shortly afterwards a lecture delivered to my students, illustrating and describing appliances for preventing such disasters, was published, and received so favourably as to run through three editions in three months. This success was due to no merits of the lecture, but because the colliery authorities were interested in the subject, and encouraged its circulation amongst the mining population.

In presenting the last edition of the lecture to the public I mentioned the growing importance of mechanical engineering to mining operations, and suggested that some one should undertake the task of dealing with winding, pumping, steam generation, sinking, hauling, boring, coal cutting, tunneling, ventilating, &c.

At that time I had no intention of undertaking the duty myself, but no one else seemed willing to engage it, the examining boards for granting mine managers' certificates said that such a book would be of great service, many of my students, past and present, urged me so strongly, and my friends amongst the mining engineers and colliery proprietors encouraged me so kindly, that, not without reluctance, but determined to do my little best, I consented, and certainly doing so was not a case of rushing into print.

The one chief aim, never lost sight of during the year which I have been engaged on the work, has been to write about the mechanical appliances connected with collieries so as to present some information in language plain enough for any one to understand.

The illustrations, also, are not intended as examples of artistic ability, but to be clearly drawn sketches of the objects they represent. With the exception of the figure illustrating Bailey's automatic fan recorder, and several figures illustrating Rigg's appliances for tipping and screening—which figures are so much better than any I could have made that there could be no hesitation in adopting them—all the illustrations have been specially prepared.

The generation which has elapsed since my practical connection with collieries commenced, and the fifteen years partly occupied in lecturing to mining students, ought to have been of some service in my effort at authorship. But the disappointment to myself that my endeavours have not resulted in something more worthy of the subject and the great mining community to whom it is with fear and trembling addressed is very great. And yet, if good intentions, hard honest work, and the feeling that one has done his best amount to anything, they may perhaps give me some claim to indulgence at the hands of those who may read what I have written.

It was originally intended that the whole work should be complete in one volume, but latterly decided it could better be divided into two. Volume I. deals with laying out surface plant, winding engines, boilers and chimneys, ropes and drums, cages and conductors, headgears and pit banks, tipping and screening, mechanical ventilation, and the steam engine indicator.

Mechanical ventilation has been far from easy to deal with, opinions, and even results, being so contradictory. I have endeavoured to put the subject clearly before my readers, and have not hesitated to quote freely from, and refer freely to, authorities eminent in matters of ventilation. As regards exhaustion and compression, just when it appeared that practically everybody was agreed that for simplicity and effectiveness the former was most suited to ventilation, arguments are being presented in favour of the latter. A leading speaker at the last meeting of the Institution of Mechanical Engineers, during the discussion on mining machinery, expressed strongly that the right principle of ventilation was to force the air through the mine. It seemed to him, and anyone not specially

connected with that branch of engineering, that when air was required for working machinery in mines, and for the men to breathe who are at work there, to keep a pressure on the face of the coal, and to dilute the noxious air, it was strange that they could not change their system to one of pressure forcing the air to the extreme ends of the mine, and thus making it flow back, instead of the plan which had the effect of increasing all the difficulties at one time.

It is probable enough when opinions like these are expressed in high quarters that the principle of compression will at least be tried at some collieries. But compression has been tried before and has not succeeded, and it is not at all likely that the practically unanimous present opinion in favour of exhaustion will be much affected. Nor is compressed air for working machinery underground likely to come into such general use. The first cost is heavy, and an average useful effect of 25 per cent. is not encouraging. It seems much more probable that power will be conveyed from the surface into the mines by ropes.

Then in dealing with centrifugal ventilators, there are contradictory ideas as to the form of fan which really gives the best results. The results of different fans, and even ot the same fan working at the same pit, vary so much that practical results certainly do not decide the question. Consequently, arguments on this subject must be largely based upon theory, and I have tried to give a fair theoretical view of the question.

Volume II. now in progress, and completing the work, will comprise such subjects as appliances for pumping, hauling, air compressing, etc., etc. These headings afford a sufficiently comprehensive range for effective treatment by the ablest pens and pencils in the engineering profession. If the present attempt to feebly deal with the subject should provoke elsewhere a worthier production in the Mechanical Engineering of Collieries, no one will be better pleased than, gentle reader,

Your obedient Servant,

C. M. PERCY.

KING STREET, WIGAN,
October, 1882.

PREFACE TO THE SECOND EDITION.

THAT a second edition would be called for within six months of the original publication is an event which my most sanguine expectations could never have anticipated. It is a sufficient proof that the mining public thought a work on "The Mechanical Engineering of Collieries" was needed, and my duty now is an exceedingly pleasant one, namely, to acknowledge the fairness and kindness, in some cases encouragements of my critics, who have done my efforts more than justice, and also to thank those of my readers who have, many of them, written to me in congratulatory terms.

Judging from correspondence, my readers have been chiefly practical men, and in this I am pleased. A practical man myself—I would even venture to say a working man—my life has been spent at collieries amongst working people, and I have endeavoured to write as nearly as possible as I would speak to colliery workmen and officials and proprietors actually engaged in mining operations.

So far as regards the prevention or lessening of the terrible disasters by explosions in our mines, which too often without a moment's warning carry havoc and destruction into hundreds of homes, no doubt increased knowledge of a highly scientific character will tend largely in this direction in the future. But, to deal with the "cause and prevention of colliery explosions" has been no part of my programme; and for this reason, and also because I am not sufficiently competent to deal with it even if I would, it forms no part of the volume already written, or the one now in progress.

Professor Tyndall in one of his lectures in London a short time ago, said that explosions in mines could be entirely avoided, and scientific men like himself were only prevented from introducing means for effecting so laudable a work because it would entail such an enormous additional expense, that coal, a necessity to the poor man,

would be placed beyond his reach. I would hesitate very much to challenge any statement made by one to whom the scientific world owes so much, and has so much confidence in as Professor Tyndall. But I do venture to offer an opinion that even our most eminent expounders of science have no knowledge at present of means whereby explosions in mines could be entirely prevented, and if Professor Tyndall is in possession of such information the mining world would be glad to know what it is.

What I do firmly believe is, that as the years go on, science unfolding itself, managers becoming more highly educated without being less practical, and workmen more intelligent and better informed, explosions will become more rare, but that they will ever entirely cease I do not believe.

Mechanical engineers have provided means by which power for ventilation is practically unlimited; and what we want now is another Humphrey Davy and another George Stephenson, that will give us a safety lamp affording a reasonable amount of light, and, under all possible conditions in mining operations be absolutely safe.

Such a lamp has not yet been brought under public notice, and I am not hopeful that Mr. Ellis Lever's commendable offer of a £500 prize will produce it. But I do hope and believe that the Royal Commission, comprising Professor Tyndall and several of the most distinguished practical mining engineers in the world, will, before they conclude their labours, do something in this direction. We think nothing of spending a few millions on an expedition to some part of the world to uphold, with very often questionable results, the honour of England. A very much less amount expended on mining research and experiment would unquestionably lessen those frightful accidents that now and again send a thrill of horror through the land; and such a lessening of loss of life at home would uphold England's honour more effectively than a barren campaign abroad.

It is satisfactory to know that the Royal Commission are having the needful appliances erected at Woolwich, with a view to continuing the safety lamp experiments previously conducted in Lancashire and South

Wales, and let us hope that some substantial result will be obtained.

But my work deals with machinery, and what we all ought to aim at is the alteration and improvement and introduction of machinery which will give us the maximum of efficiency, economy and safety. Accidents by machinery we can prevent and ought to prevent.

It is a reflection upon the age in which we live that steam boilers and vessels for compressed air should burst. In the very month preceding this an air vessel has burst at Ryhope, but fortunately without causing loss of life; a steam boiler has burst at Chorley, sacrificing two lives; and from France word comes to us of a boiler explosion causing as much fatality as a disastrous accident in a mine. Such accidents as these might be prevented and should not occur. During the past few months also there have been several cases of winding ropes breaking. Boilers well made, of good material, in charge of competent men, and worked with a sufficient margin of safety, should come to no harm. Ropes of plough-steel, well manufactured, working on proper machinery and properly inspected, will work for years without injury.

And then as to our winding engines. Increasing depths from which coals are drawn require appliances to deal with heavier loads in shorter periods, and without extravagance. In the course of an address which I had the honour of delivering to the North Staffordshire Institute of Mining and Mechanical Engineers on winding appliances, I expressed the belief that future improvements would combine automatic expansion gear, separate condensers, and some such arrangement as the Kœpe, which dispenses with winding drums. Mr. Henry Davey, famous in winding machinery improvements, has successfully applied separate condensers which obtain a fairly good vacuum during a winding, and do not complicate the engine or interfere with the working. Mr. Arthur J. Stevens has applied at several large collieries in the South and in the North an automatic expansion gear which makes the engine easier to work, leaves the action of the valves unaffected at each end of the journey, or during a slow winding, and comes into operation at high speeds, cutting off the steam at as slight a proportion of the

stroke as one-sixth. This appliance, attached to winding engines raising 500 tons daily from a depth of 400 yards, is effecting an economy in consumption of valuable fuel to the extent of nearly 400 tons per annum. The Bestwood Coal and Iron Company have now had several years' continuous experience with the Kœpe, which enables smaller engines to do the work, and gives no serious trouble.

The period through which we have scarcely yet passed, a period of harassing adversity following one of unhealthy because exceptional prosperity, has made colliery proprietors hold their hands against alterations which would be even beneficial and economical. But for the coal trade there are happy times in store: the demand goes on increasing, and the production does not and cannot continue to increase in the same proportion. A two-fold result will be arrived at—the trade will be profitable, furnishing the means for adopting improvements, which improvements will be essential to adapt the supply to the demand.

We who are interested in the engineering of collieries should all strive to make the whole of the machinery as perfect as human ingenuity can make it in the direction of efficiency, safety, and economy; and no better introduction to such a condition of things can be made than by becoming thoroughly acquainted with the appliances of the present time. Towards this desirable result possibly "The Mechanical Engineering of Collieries" may render some little assistance. If so, it will have fulfilled some useful purpose, and more than satisfied the highest ambition of its author,

C. M. PERCY.

THE WIGAN MINING
AND MECHANICAL SCHOOL,
May 1, 1883.

NOTE.—Many correspondents have made enquiries as to the probable date of publication of the second volume, completing this work. The indulgent consideration given on all hands to the first volume makes me especially anxious that the second shall not cause feelings of disappointment, and for nearly a year it has had more or less of my attention. The preparation of some 200 special illustrations takes a long time, but I am as anxious as any one for its completion, and I shall steadily continue my preparations for its production.

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MECHANICAL VENTILATION.

THE MECHANICAL ENGINEERING OF COLLIERIES.

CHAPTER I.

LAYING OUT SURFACE PLANT.

Underground Conditions determine Site of Shafts—Mechanical Engineer makes all Surface Arrangements—Determines Type and Size and Position of Appliances—Temporary Appliances for Sinking—How Fixed—Daily Outputs of 250, 500, and 1,000 tons—Horse-power for Pumping—For Ventilating—For Winding—Position of Winding Engines—When Round Ropes and when Flat Ropes are used—Number of Boilers—How determined—Position of Ventilating Fan—And of Pumping Engine—Arguments for and against Cornish Engine—Inconvenience of Cornish Pumping Engine—Position of Capstan Engines—Position of Boilers—Railway running past the Front—Arrangement of Railways—Number of Railways—Inclination of Railways—Position of Workshops—On Bank or on Ground Level—Stocking Ground—Arrangements to prevent Formation of Ice in Downcast—And to allow exit of Air from Upcast—Intake and Outlet—General Principles which should govern Laying-out of Surface Plant.

THE amount of skill and forethought in deciding upon the general surface arrangements of a colliery is second only to what is required in actually opening out and working the mine. Of late years some very fine plant has been erected in a manner beyond criticism, but in the majority of cases there seems to be no order, no system, no connectedness in that part of collieries which is placed upon the surface. So far as underground matters are concerned the mining engineer by no means has things all his own way, and certain defectiveness and inefficiencies are more his misfortune than his fault; but the mechanical engineer knows exactly what he is going to do, and, needing nothing but a fair field and no favour, he should go in and do it.

The position of the colliery itself is determined by underground necessities—that is to say, that even as

between one field and the next, circumstances below-ground determine in which field the pits should be sunk; but beyond this mere determining the exact position the mechanical engineer is master of the situation. He determines the railway conveniences, the style and size and position of winding engines, the form and number and site for boilers, the working pressure of the steam, the machinery for pumping and ventilating and for cap-staning, the designing and fixing the pitbanks and the headgears, and in the event of the colliery being self-contained, and not dependent upon a central establishment, to place conveniently the needful workshops. There seems scope enough in this to allow the action of a considerable amount of engineering experience.

The practice is now very generally adopted in laying out a new colliery to put down the shafts and deal with the water made whilst sinking with temporary appliances.

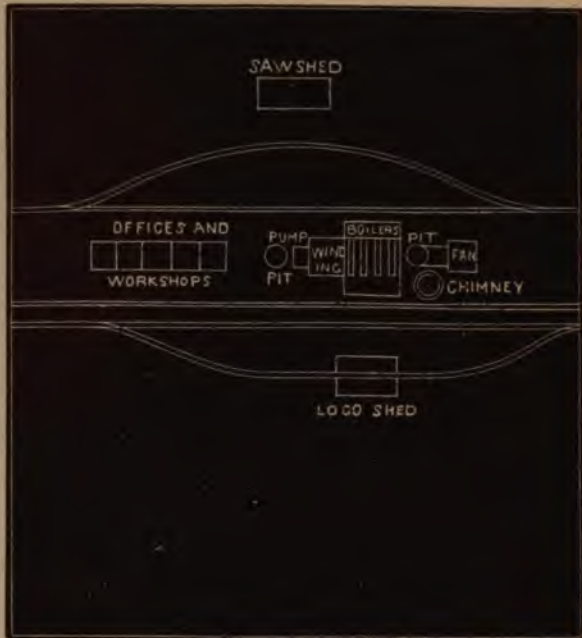
There is a two-fold advantage in this; first, in the event of disappointment when the shafts have been sunk, the enormous expenditure of an extensive permanent plant is avoided. Second, even where there is no disappointment, and where the results are an absolute certainty from the beginning, time is saved, because sinking and erection of permanent plant are in progress at the same time. For such work as this a very excellent class of machinery has come into use, named the semi-portable, which can be used for winding or pumping or ventilating. These engines, comprising the means of generating their own steam, can be taken into a ploughed field and be at work in a few days. They are also marvellously economical, and the large amount of work with the small weight of coal that an engine occupying little space can perform is very striking.

In making temporary arrangements such as these, the one point should be to so place all such machinery that it is not in the way of the permanent erection.

The facts on which the arrangements of a permanent character are based are very simple. We must know approximately, first, the depth and daily output; second, the make of water and the depth; third, the horse-power required for ventilation. These facts enable us to decide as to the whole affair, and we can arrive at the size of

Fig. 1.—Surface Arrangement for Daily Output 250 tons.

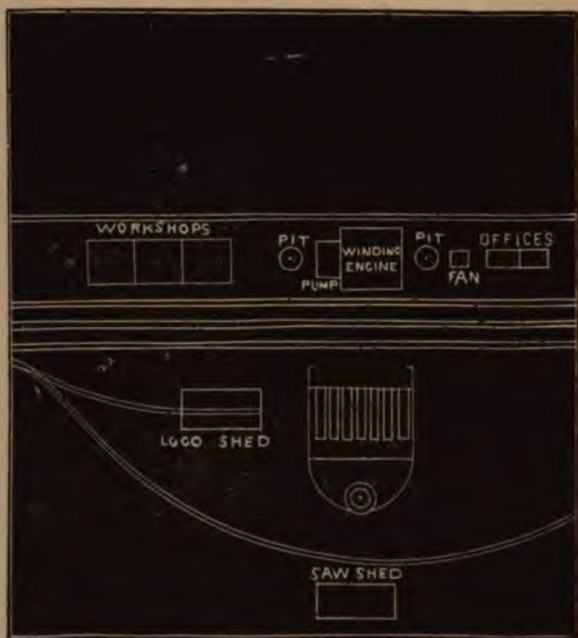
Timber Yard. Timber Yard.



Stocking Ground.

Fig. 2.—Surface Arrangement for Daily Output 500 tons.

Stocking Ground.



Timber Yard. Timber Yard.

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engines for winding and pumping and ventilating, the number of boilers, and all the rest of it. We purpose treating of winding, pumping, ventilating, and steam generation separately, each in its proper place, and will only touch upon them here collectively and briefly.

We take as examples three colliery arrangements for daily outputs respectively of 250, 500, and 1,000 tons; and from depths of 400, 500, and 600 yards. (See figs. 1, 2, 3.) Winding engines suited to these requirements would be about (1) 24 in. cylinders by 4 ft. stroke; (2) 30 in. cylinders by 5 ft. stroke; (3) 36 in. cylinders by 6 ft. stroke. How we arrive at these figures will be shown at the proper time. The probable average horse-power during a working day would be 250, 500, and 1,000. We will assume an equal amount of water in each case, 20,000 gallons per hour, from a depth of 150 yards, and the horse-power would not fall much short of 100. And lastly, as regards ventilation, it will suffice for our present purpose to assume respective horse-powers of 100, 200, and 400. We fix no size of pumping engine, because it might be a slow-working and single acting, or a quicker speed and double action. And in ventilation we might have either a large "Guibal" moving slowly, or a small "Schiele" revolving rapidly. All we require at present is the respective horse-powers, which we work out as follows:—

First, output of 250 tons from 400 yards: winding engines 250; pumping engines 100; ventilating fan 100; equal to a total of 450 horse-power. Second, output of 500 tons from 500 yards: winding engines 500; pumping engines 100; ventilating fan 200; equal to a total of 800 horse-power. Third, output 1,000 tons from 600 yards: winding engines 1,000; pumping engines 100; ventilating fan 400; equal to a total of 1,500 horse-power. This now enables us to fix upon the number of boilers in each case.

There is no more popular and certainly no better steam generator for collieries than the well-known "Lancashire," which is simply a "Cornish" boiler with two flues, and which will hereafter be described fully. The usual size is 7 ft. diameter, by 27 or 28 ft. long, and such a boiler is equal to raising steam for 200 horse-power.

We ought always to have, in each range of six boilers or less, one spare one for cleaning or repairs. Therefore in our example the 250 tons output requires four boilers, the 500 tons output five or six boilers, and the 1,000 tons output ten boilers.

We are supposing that in each case we have two shafts, the downcast for the pumps and for winding all the coals, and the upcast used exclusively for ventilation. We shall therefore have two cages working in the downcast shaft, and all the banking and screening concentrated upon one stage. But as the subject of screening is dealt with in chapters eleventh and twelfth, we shall not refer to them here, except to say that for the larger output of 1,000 tons per day we should provide railways and screening arrangements on both sides of the pits.

The position of the winding engine house depends upon the winding machinery. (See figs. 4 and 5.) If flat ropes and vertical drums are used, the distance from the centre of the pit to centre of drum need not exceed 15 or 18 yards; but if round ropes are used 30 yards is found a better distance, because in the one case there is no side movement of the rope, whilst in the other case there is considerable. The fan and its engine will be placed as close to the upcast as possible. The pumping engine in cases where the amount of water to be dealt with is very great, amounting to quantities varying from a quarter of a million to half a million gallons per day, and consequently the rams very large, and the engine cannot well be placed underground, is usually of the Cornish type, and if so, stands over the pit, which is not convenient unless the shaft is used only for pumping. Its position interferes with the banking. When the water is not so considerable, but still the engine cannot conveniently be fixed underground, a useful purpose is served by having a horizontal engine stationed under the stage and on the same side as the winding engine. Figure 6 shows plan of pit and Cornish pumping engine.

The capstan engines can very well be placed in the cellar of the winding engine house (see fig. 7), and so be in the way of nothing, and still convenient in case of need. It will be seen that the whole of the machinery for which the boilers have to supply steam is placed compactly, so

as to be nearly equi-distant from the source of steam supply.

In fixing the boilers we want to have them in close proximity to the engines with which they have to be connected. The reason for economy in portable and semi-portable engines is that the steam travels no distance in getting to the cylinder, and in all cases just as we shorten the travel of the steam so do we lessen the waste by loss of heat. The range of boilers should have their fronts parallel with the line of railway, for convenience in putting slack into fire-holes and conveying ashes away. In many instances the fuel for the boilers comes from the pit, and can be brought from the stage in the tubs as they come out of the pit. But slack is not separated from the coal underground at all collieries, and even if this is so the fuel, such as cannel, may be too valuable, even as slack, for generating steam, and inferior fuel has to be brought from some other point. In every case, whatever the arrangement may be as to fuel, the fronts of the boilers should be parallel with a line of railway.

The distance from this line of railway should be about 6 yards, to afford room for slack, and a convenient firing level is in line with the wagon bottoms, which means some 4 ft. above the rails. Arranging the boilers at this line answers well for the engines they have to supply, because we can have all the cylinders so much higher than the boilers that priming is unlikely. (See fig. 8.)

The arrangement of railways will depend as to whether or not an existing line passes the colliery. In such a case we simply branch off above and lay out the needful lines and join on again below. (See fig. 9.) But we had better assume that no railway exists at all near the colliery, and everything has to be made. We lay out a line of railway which shall answer for the bringing in of empty wagons and the taking out of loaded wagons, and all the others must branch off this. (See fig. 10.)

Most good collieries now have locomotive power; but in view of contingencies, such as the locomotive being out of order, or being engaged elsewhere, we should provide such railway accommodation that we have (1) accommodation above the colliery for empties sufficient for an entire day; (2) room below the pit for a day's loaded wagons to

stand; and (3) the railways such that all these empties can run in and all the loaded wagons run out by gravitation. We want as many separate lines as there are separate classes of fuel, and one additional for putting empty wagons up. The railways should have an inclination not less than $\frac{3}{8}$ in. nor more than $\frac{1}{2}$ in. per yard. The space between each line of railway should be two yards.

For a small establishment all the workshops may very well be placed on the pit bank, as shown in Chapter XI., figure 121; but for a colliery with an output of 1,000 tons a day a more elaborate line of workshops will be needed than it is possible or desirable to have upon a stage, and these should be placed upon the ground level. These shops will comprise smithy, boiler shop, fitting shop, wagon and carpenter's shop, saw shed, and locomotive shed, and either adjoining or in close proximity, an office and a store room.

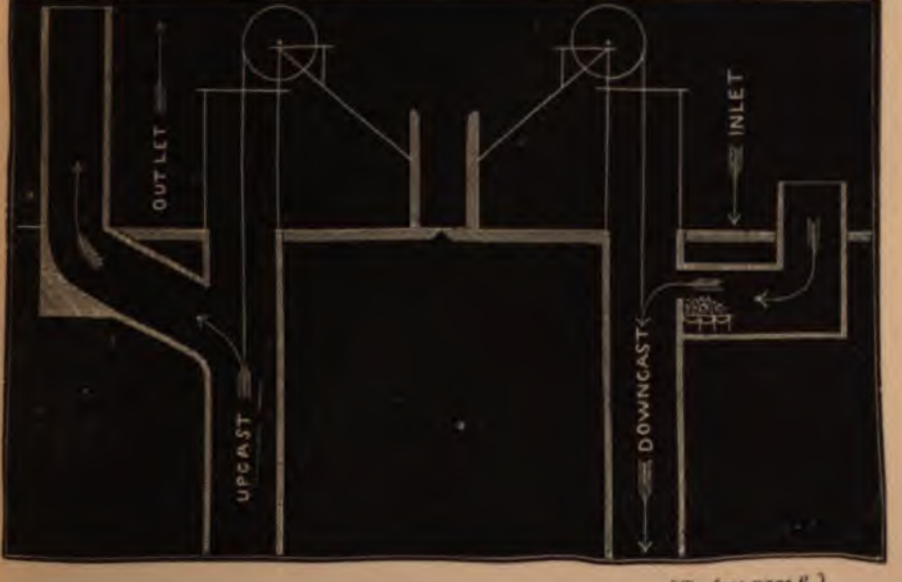
In connection with all collieries we require convenience for putting coals down when business is slack, and for filling into wagons when trade is brisker. This ground should be convenient to the pit, and an engine should be placed upon the pit bank for drawing the coals from the stocking ground on to the stage for the purpose of screening. (See Appendix, Note A.)

The surface arrangements of a colliery would be incomplete unless some provision were made for airing the downcast in the winter time. In very cold weather ice forms in the shaft, especially if, as in our case, the shaft is also used for pumping or for winding water, and these pieces of ice being liable to break off, may be a fruitful source of danger. To avoid this danger an "intake" is made into the downcast, and in this "intake" is placed a grate, in which, in the severe weather, a fire is maintained, which heats the air passing in, and prevents the formation of ice. This "intake" answers another useful purpose. The lower landing is often used for sending underground bricks, mortar, props, &c., and the cage standing at this point baffles the air, and prevents its free entrance into the shaft. The "intake" being below this level overcomes this difficulty by increasing the area for admission of air. When upcast shafts are used for winding, and especially if a furnace shaft, a similar arrange-

Fig. 9.—Railways arranged on one Side of Pit.

Fig. 10.—Railways arranged on both Sides of Pit.

Fig. 11.—Inlet and Outlet to assist Ventilation.



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ment is made as an "outlet," and not only allows free exit, but conveys away the furnace smoke, which under other circumstances would seriously obstruct banking operations. (See fig. 11.)

The foregoing remarks are intended to explain the general principles which should guide the mechanical engineer in laying out the surface arrangements of a colliery. We should have power for winding, for pumping, for ventilating, for capstaning, and for the generation of steam, and these appliances placed conveniently to each other and their respective works. We should have railway facilities such that the receipt of empty wagons and despatch of fuel is free from hitches and can be accomplished by the least possible work. We should have the shops and offices and stores needful for all possible contingencies compact with each other, and convenient to the colliery. We should have all the equipments of the colliery such that the various parts adapt themselves to each other, that work can proceed without bustle and confusion, and, in short, that the whole establishment shall proceed from day to day like the arrangements of a well-constructed machine.

We have simply in the first chapter shown how, knowing the amount of work to be done, and the site, the whole surface plant for a large or small colliery can be arranged.

CHAPTER II.

WINDING ENGINES.

Importance of Winding Engines—Peculiarities of Winding—Requirements of Winding Engines—Beam Engines—Geared Engines—Single and Pairs—Vertical Engines: their Advantages and Disadvantages—Horizontal Engines: their Advantages and Disadvantages—Direct-acting Horizontal Engines in Pairs the Best—Under and Over-Ropes—Condensing Engines for Winding—Various Kinds of Condensing Arrangements—Difficulties in applying Condensing Engines for Winding—Example of Engines to raise a Load of Two Tons of Coal from a Depth of 500 Yards—The Total Load at Starting—The Pressure of Steam—The Diameter of the Drum—The Stroke of the Engine—A Pair of Engines to be used, and one to be equal to starting the Load—Allowance of Power for Friction and Inertia—Average Speed of Piston—Time of a Winding—Period allowed for Banking—Approximate Horse-power of Engines—Average Pressure of Steam.

We now reach the most important of all colliery machinery, and the appliance which either does or ought to do the lion's share of the work. That colliery is prosperous and its proprietors happy at which powerful winding engines can be kept busy.

In earlier times there were many classes of engines in use for winding—beam engines and geared engines, single engines and coupled engines, horizontal engines and vertical engines. In our time we are all agreed that there is only one really useful type, and that is the direct-acting.

The operation of winding is so different from any other mechanical work at collieries that arguments which apply to pumping or hauling, ventilating or capstaning do not apply to winding. Pumping and ventilating are continuous operations, extending over entire days; hauling is an operation which at least occupies several minutes, and capstaning is slow and lasts for some time. Winding is peculiarly intermittent—a whole performance only occupies from twenty to sixty seconds. This includes starting, getting up speed, slackening and stopping—

ndeed every variation from sixty miles an hour to rest. It may almost be said that no two strokes of a winding occupy the same time, and we have already said sufficient to show that both beam engines (which would get broken) and geared engines (which would smash) are alike unsuitable, and no engine will at all answer that is not direct-acting.

We want great speed in a winding engine, because the possible load at one time, even at the furthest extent, is so slight that to do anything like work we must do a large number of windings in one day, and hence great speed is essential. We want enormous power, because we have only an exceedingly short time to do a whole winding; the period for getting up speed is therefore small indeed, and although the actual load of fuel is slight, when we reckon up the cages, the tubs, the ropes, and the engines themselves, all of which have to attain a terrific speed in a few seconds, we realise the great power requisite in winding engines.

There is no need in this chapter to discuss this point; everybody whose opinion is worth having has decided that direct-acting engines are the only engines for winding, and we may go further and say they should be coupled. (See Appendix, Note B.)

There is some difference as between the vertical engine and the horizontal. It is contended for the vertical engine, first, that it costs less; second, it occupies less ground space; third, the piston works more equally in the cylinder; fourth, the winding drums being higher, the rope needs to coil a little less distance round the head-gear pulley. (See fig. 12.)

But, on the other hand, we may argue, first, the engine pillars cost more; second, a higher engine-house is required; third, the ascending and descending pistons do not balance each other; fourth, if the pulleys are large enough and properly turned, the drum being a little lower or higher makes little difference.

The writer wishes to say not one word against the vertical engine, but simply asks to give his reasons for thinking the horizontal engine the best. First, the engineman has his engine within sight; second it is easier got at for cleaning, oiling, inspection, and

repairs; third, expensive engine pillars are not needed; fourth, the whole structure presents a handsomer appearance.

There is really next to nothing in the argument about the ropes having to come further round the pulley. What does play the mischief is in the case of the "under" rope which has to bend one way round the pulley and the opposite way round the drum. The real remedy for this is to have no "under" rope, but to have two "over" ropes, as shown in fig. 13. But this, of course, can only apply when we have only one rope in each pit, and the pits on opposite sides of engine-house.

Nor is there anything in the argument about horizontal cylinders being so much worn at the bottom, because, as a matter of fact, it is not so, and with cylinders a yard in diameter it can be shown that there is little if any more wear below than above.

Let us consider it settled that the horizontal engine is at least as suitable as any other. We now want to know shall we work condensing or non-condensing?

In the North of England a good many winding engines work condensing; that at Monkwearmouth is describe in Chapter VI., and may be taken as a good example of its class. In the Midland counties the usual form of high-pressure engine has sometimes a connection with a separate engine working a condenser which works continuously, and the winding engine intermittently. At the Bestwood Collieries such an appliance was at work for some time, and was so arranged that by the mere closing or opening of two taps, the engines worked non-condensing or condensing as required. But no great success attended it, and the condensing arrangements were often out of order, and were giving so much trouble that the probability was they would be dispensed with. Winding is certainly not the operation where condensing has a fair opportunity, in consequence of its enormous speed, extremely intermittent and very irregular character. And further, an essential of a good winding engine is that it shall be equally powerful everywhere in its revolution. We may have to stop or start at any point between the top and the bottom of the pit, and life may depend on there being no sticking places. The great majority of colliery proprietors who

FIG. 12.—WINDING ROPES ON VERTICAL AND HORIZONTAL ENGINES.

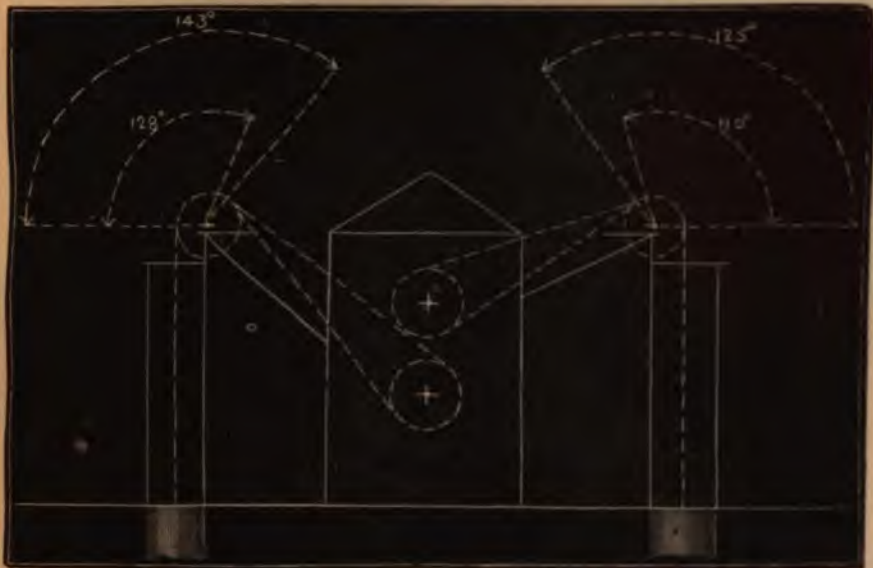
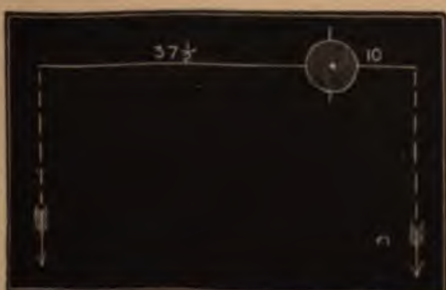


FIG. 13—TWO OVER ROPES.

FIG. 14.—POWER OF ENGINE AND RESISTANCE OF LOAD.



RESISTANCE, CIRCUMFERENCE, LOAD. POWER, STROKE, PRESSURE, AREA OF PISTON.

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have adopted the non-condensing engines for winding have had considerable justification for so doing. For the present we will deal with such engines, and the first thing of all is to show how we arrive approximately at the size of winding engines required. And as these chapters are written not, as an author once said, "by a gentleman for gentlemen," but "by a practical man for practical men," the writer's intention is to avoid all complicated rules and formulæ, and to work out his calculations practically.

We will suppose a pit, 500 yards deep, from which we propose to raise each winding two tons of coal, and we propose to have a pressure of steam at boilers which shall not fall below 60 lb. per square inch.

A cage to carry two tons of coal will probably weigh two tons itself, and the tubs 15 cwt., making a total of 4 tons 15 cwt. at the end of the rope. A round steel winding rope, weighing 4½ lb. per yard, has a safe working strength of 6 tons, and such a rope for 500 yards weighs as nearly as possible 20 cwt., which added to 4 tons 15 cwt. gives 5 tons 15 cwt. as the actual load upon the rope at the drum end. But what we want to know is the load which the engines have to start, and as the two cages and their tubs balance each other we simply have two tons of coal and one ton rope = a total of three tons, allowing for the moment no compensation in the drum.

We will assume also the diameter of the first coil upon the drum 12 ft. = 37½ ft. circumference, and the stroke of the engine 5 ft. = 10 ft. travel of piston each backward and forward stroke. We have now this simple problem, a resistance of three tons at the end of a lever 37½ ft. long, and we want to know the power needed to overcome this at the end of a lever 10 ft. long. (See fig. 14.)

The resistance or weight is 37½ × 3 tons = 112½ tons = 252,000 lb., and the power will be 10 × 60 = 600 × something which will equal 252,000; 252,000 ÷ 600 = 420, and this evidently means the area of the piston in square inches. Add one-half for overcoming friction, 420 + 210 = 630 square inches, area of piston = 28½ inches diameter, without making any allowance for area of piston rod. It will be sufficiently near for our present purpose to call it 30 inches diameter and 5 ft. stroke. It will be observed,

first, that we have calculated only upon one engine, because the other at the point of starting may be powerless (see fig. 15), and in case of accident it is well that one engine should be equal to starting the load; second, that we assumed full boiler pressure of steam upon the piston; of course that will be so at commencement of winding; and we allow one-third of the whole power to overcome friction in inertia, this is a somewhat large allowance, but it is well with winding engines to be liberal. So far, then, we have arrived at this fact, that with a drum the smallest coil of which is 12 ft., and the steam pressure 60 lb., engines 5 ft. × 30 in. will start our load. Now, what can we raise in an hour? The load at the bottom is 5 tons 15 cwt., and at top 4 tons 15 cwt., therefore 5·75 × 12 = 69·00 ÷ 4·75 = 14½ ft., the diameter of the top coil; and 14½ + 12 = 26½ ÷ 2 = 13¼ ft. the average diameter = 41⅔ ft. circumference; and 500 yards = 1,500 ft., the depth of the pit. 1,500 ÷ 41⅔ = 36 revolutions × 10 = 360 ft., which the piston has to travel each winding. These engines will very well run at an average piston speed of 400 ft. per minute; therefore 360 × 60 = 21,600 ÷ 400 = 54 seconds, the time of winding. Allow 36 seconds for banking, which gives the total time for winding and banking 1½ minutes, representing 40 windings = 80 tons an hour. Now then, as to approximate horse-power at which these engines will work. The cylinders are 30 inches = 706 square inches area, the average piston speed is 400 ft. per minute, and the average effective pressure may be assumed two-thirds of boiler pressure = 40 lb. Therefore, 706 × 400 = 282,400 × 40 = 11,296,000 ÷ 33,000 = 342 × 2 = 684 horse-power. This 684 is the horse-power during actual winding, which is 54 seconds in each 1½ minutes. But considering the engines as to their continuous horse-power over an hour, the horse-power exerted per hour will be not nearly so much as 684.

Having thus introduced the subject, we proceed to describe a pair of horizontal, direct-acting, high pressure winding engines, calculated to work with 60 lb. per square inch of steam pressure.

FIG. 15.—ONE ENGINE OF A PAIR ON CENTRE.

FIG. 16.—SECTION OF WINDING ENGINE BED PLATE.

FIG. 18.—JOGGLES ON BED PLATE FOR PEDESTALS.

FIG. 17.—JOINT IN BED PLATE.

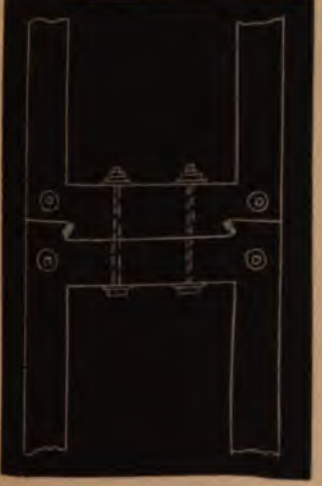

FIG. 19.—FEET OF CYLINDER TO REST ON BED PLATE.

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CHAPTER III.

WINDING ENGINES.

Horizontal Non-Condensing Engines in Pairs—Size of Cylinders and Length of Stroke—Depth of Pit—Load each Winding—Period of Winding—Average Piston Speed—Output in Tons per Hour—High Piston Speed of Winding Engines—Favourable Conditions for High Speed—Balancing the Load—Methods of effecting it—Defects of Unbalanced Arrangements—Proportion of Stroke to Diameter of Cylinders—Steam Pressure—Advantages of High Pressure—Lancashire Boiler—Strength of Cast Iron and Wrought Iron—Foundation Plates—Principles of Construction—Advantages of being cast in Pieces—Preparations for Cylinders and Slide Bars and Pedestals—Cylinders—How bored—Length of Cylinder—Thickness—Allowances in Thickness—Feet cast on—Branches for Steam and Exhaust—Area of Steam and Exhaust Passages—Waste Water Branches—Relief Valves—Clearance at Ends of Cylinder—Cover—How secured to Cylinder—Bell-mouthing Cylinders—Pistons—Piston Rings—Cast Iron—Wrought Iron—Size of Rings—Number of Rings—Piston Rods—How secured to Piston—Size of Piston Rods—Back Piston Rods—Supposed Advantages—Experience at Rose Bridge—Valves and Valve Boxes—Defects of Slide Valve—Advantages of Cornish Valves—Ball and Socket Joint—Valve Motion—How worked—Drag Cranks—Counter Shafts—From Main Shaft—Expansion in Winding Engines—Difficulties—Automatic Expansion Gear—Silksworth Colliery—Grange Iron Company—Uskside Company—Slides and Slide Blocks—Connecting Rod—Proportions—Crank and Crank Pins—Wrought and Cast—Crank Shafts—Strains upon Crank Shafts and Crank Pins—Journals—Pedestals—Angle Pedestals—Requirements of a good Throttle Valve—Winding Indicators to show Position of Cage during a Winding, and to record Number of Windings.

We take as an example of non-condensing winding engines a pair of horizontal direct-acting with cylinders 30 inches in diameter and stroke 5 feet, calculated to raise a load of two tons of coals from a depth of 500 yards in 54 seconds, running at an average piston speed of 400 feet per minute, and giving an output of 80 tons per hour. There is no exaggeration in this speed, because there are many winding engines working at a higher velocity, and several with which the writer is acquainted having a maximum piston speed of 1,000 feet per minute.

The amount of work capable of being performed seems large, and the weight of fuel dealt with at each winding and per hour seems considerable, but we must bear in mind that the engines are supposed to work under favourable conditions as regards balancing. The ropes are round, and are arranged so that the load is uniform throughout the winding, either by having a cylindrical drum and a tail rope placed under the cages, or by having a spiral drum such that the load and the diameter is a uniform quantity. This makes a great difference, because with other arrangements we should have an amount of useless weight commencing each journey, requiring more power and retarding the speed.

It will be observed also that the stroke is twice the diameter. The longer a cylinder is, the less surface does it expose to the action of the atmosphere in proportion to the capacity. A cylinder whose length equals double its diameter gives a well-proportioned engine, and for winding is pretty usually adopted.

The steam pressure is taken at sixty pounds, which although less than many colliery boilers now work with is much in advance of the pressure formerly used. Our reasons for adopting this pressure are very simple. High pressure steam is economical, because as we get higher up the proportion of what is wasted, or rather not utilised, to the whole pressure must be less as the pressure is higher to begin with. The boiler now most popular, because at once quick in generation and economical, namely, the Lancashire, works quite safely and allows a large margin of safety at from sixty to seventy pounds pressure and without the need of having plates inordinately thick. Therefore we have fixed upon a steam pressure of sixty pounds per square inch.

We shall also assume that in these engines all the cast-iron is equal to a safe working tensile strain of 2,800 pounds per square inch, and the wrought iron equal to a safe working tensile strain of 4,480 pounds per square inch.

Foundation Plates.

These shall be two in number, made of good tough cast metal, constructed on the box principle, as shown in fig. 16. What we want in these foundation plates is a

maximum of supporting strength with a minimum of material. The method sketched accomplishes this; it is very light and exceedingly strong, and it enables the shafts, &c., to be thrown high enough up for the cranks and rods to clear the engine pillars. Each of these foundation plates to be cast in two parts, which must be jointed and keyed and bolted, as shown in fig. 17.

The object of this casting in parts is threefold; (1) it is better for making and casting; (2) it is more convenient for transit by road or rail; (3) it is more easily and efficiently put into its position. With small winding engines a foundation plate is not very long, and will do well enough in one length. But with engines having cylinders 30 and 36, and even 48 in., such a plate in one piece becomes quite unwieldy, and there is no advantage in it, because the joint as shown makes the two pieces to all intents and purposes one. The foundation plates must be long enough to carry cylinders and slide bars for a stroke of 5 ft., and to allow a connecting rod 15 ft. long, and to have preparations to receive crank shaft pedestals, such preparations to have strong joggles to key the pedestals against, as shown in fig. 18. The foundation plates should be planed on the bottom, so as to enable the plates to lie level upon the engine pillars, and such planing should be parallel to the centre line of the engines.

Cylinders.

To be made of cast iron, tough and workable. (See Appendix, Note C., giving the opinions of eminent engine makers as to what mixtures of metal have given the best results in cylinders.) The iron should be tough, to do the work to which it is exposed, such as will not quickly wear away, and will preserve a smooth surface, and be easy to work with the boring tool. These cylinders to be bored horizontally to 30 in. diameter. It is considered good practice in engineering to bore a cylinder in the position in which it has to work, because, suppose a large cylinder be bored vertically and has to be fixed horizontally, the circle of the interior will become slightly oval. The length of the cylinders to be sufficient for a 5-ft. stroke, and allow room and clearance for pistons. The thickness of metal in barrel and in the flanges to be 1¼ in., and

working out the working pressure which such a thickness will be equal to we find as follows :—2,800 × 1¼ = 3,500 × 2=7,000 ÷ diameter, 30 in.=233 lb. pressure per square inch, whilst we only propose to have 60 lb. But we have to allow for a lot of things. The cylinder will wear away inside and have to be re-bored; it will wear away to some extent outside; and being of considerable length requires some thickness to support itself horizontally. Both flanges of cylinders must be faced, and each cylinder must have feet cast on to connect to foundation plates, and be connected thereto with bolts. (See fig. 19.) Each cylinder to have two branches cast on near the ends, and faced to receive Cornish valve boxes. The area of the opening to be, for steam, 19 × 3¾ = 70 square inches, and for exhaust 19 × 4 = 76 square inches. A good rule for area of steam passages is, supposing the piston speed an average of 600 ft. per minute, make them one-tenth the area of the cylinder, and in all cases let the exhaust passages be slightly greater than this. Although the speed calculated for engines now being dealt with is 400 ft., and therefore the area of steam passages would be about 47 square inches, it is a good fault with winding engines to have large openings; therefore the passages have been proportioned as if the speed were 600 ft. per minute, which, indeed, it will be at some part of each winding. One 3-in. branch to be cast on the bottom near each end, and to have a 3-in. valve connected to each branch for freeing the cylinders of water. In many cases valve appliances are attached, which keep closed when the cylinder is free of water, but open when water has accumulated, and allow the piston to send the water out. There ought not to be any difficulty in attaching relief valves, which shall prevent the accumulation of water within the cylinder producing injurious results, and as a matter of fact the best modern engines have such appliances, and they work well. There have, however, been cases where such valves have not acted when they should, and the piston operating like a hydraulic ram has forced the cylinder end out. Some, for this reason, prefer simply to have large waste water taps, to be left slightly open whenever the engine is idle, and closed almost immediately after resuming work. Each cylinder to be so that the clearance between piston and cylinder cover at end of cover shall not

Fig. 20.—Steam and Exhaust Branches and Cylinder Cover.

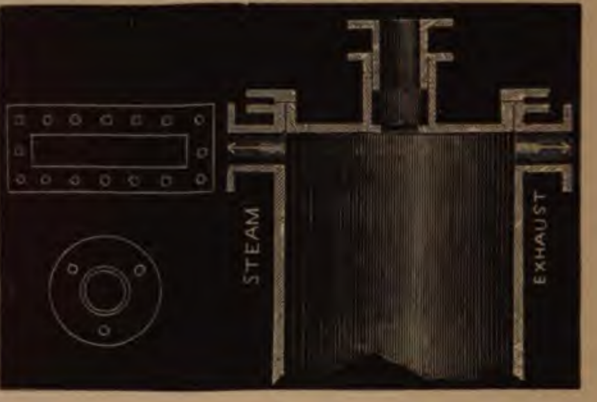

Fig. 21.—Arrangement of Bolts in Cylinder Cover.

Fig. 22.—Piston with two Rings in one Groove.

Fig. 23.—Piston with three Rings each in Separate Groove.

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exceed half-an-inch. It is important, in any engine, not to have much of this clearance, because it means so much steam wasted each stroke, but it is of special importance in the winding engine, which at best is a machine most extravagant in its steam consumption. A cylinder cover 1¼ inch thick to be fitted to each end of each cylinder, each cover to have three holes for set screws for removing the cover, and to be attached to cylinders by twenty bolts, each one inch diameter. (See fig. 21.) Each cover to be dished and turned to fit easily into cylinder. The front cover of each cylinder to be furnished and fitted with a cast-iron gland, bushed with brass, each gland to have three bolts one inch diameter. The covers to be cast hollow and filled with an effective non-conducting composition. Each cylinder to measure 30¼ in. diameter at each end, so that the pistons may clear themselves in working. Fig. 20 shows a section of one end of a cylinder, and presents a steam passage and exhaust passage and the cylinder cover with its gland and stuffing box.

It will be observed that the ends of the cylinders are to be protected, and this should always be done, but whilst the barrel portion receives the most careful attention the ends very often receive no protection at all. If the cylinders are not made somewhat larger at the ends the piston will form a collar, and thus make it difficult to get piston rings in and out. Then, as regards the cover fitting easily; this forced itself upon the writer from a cover which did not fit easily fastening itself so firmly that the dish remained in the cylinder and the rim part came away. Thinking that, as the engine was high pressure, nothing could go wrong if the rim were simply bolted on again, this was done, and several days afterwards the dish portion was drawn, or rather forced, by atmospheric pressure several inches into the cylinder, showing that a partial vacuum can and does form in a high pressure cylinder. Wedging a cover off with chisels and wedges is a risky operation, and the three screws named are found useful in avoiding this.

It has already been shown how the strength of cylinders may be calculated, and it will be well to see how the strength of cylinder cover bolts to resist the pressure brought to bear upon them can be arrived at. A cylinder

30 in. diameter has an area of 706 square inches, and this multiplied by 60 lb., the steam pressure per square inch, = 42,360 lb. pressure upon each cylinder cover. A bolt 1 in. diameter will, measuring at bottom of thread, have as nearly as possible ½ square inch area × 20 bolts = 10 square inches area; and reckoning safe working tensile strength of such bolts 4,480 lb. per square inch = a total working strength of 44,800 lb., as against 42,360 lb., the total pressure.

Pistons and Rods.

Each cylinder to be fitted with a metallic piston fitted with cast iron rings, each ring turned from a casting one-thirtieth greater in diameter than the cylinder. There are as many kinds of pistons and rings as there are kinds of engines, but it is not proposed here to deal with pistons generally. Those which answer best for winding engines are shown in figs. 22 and 23. In the one case we have two rings in one groove, and the advantage is that steam, although getting past the one ring at the joint, cannot get past them both. In the other case we have three separate rings, each in its separate groove, and the benefit is that we have a longer, without having a larger bearing surface for piston in the cylinder. Either kind gives good results, and certainly for winding engines cast iron rings are most popular, and deservedly so. The size of ring for a piston 30 in. diameter is 1 in. square, and the size increases or decreases one-eighth with each 6 in. diameter. In consequence of the piston ring being turned from a casting larger in diameter than the cylinder in which it has to work, the ring when pressed to enter the cylinder will not be a true circle, and therefore not an accurate fit. The wear soon remedies this defect, but the method sometimes adopted of cutting and pressing the piston ring before turning ensures an accurate fit from the commencement. The piston rods to be 5 in. diameter, and be screwed into the piston and riveted behind. Figs. 24, 25, and 26 show the three methods of securing piston rods. Cottering is the worst form, and screwing is the best. Cotters will come out, and the cylinder end is knocked out, and nuts get unscrewed, and the same result follows. As to the diameter of the piston rod, a rough and ready

FIG. 24.—PISTON SECURED TO ROD WITH COTTER.

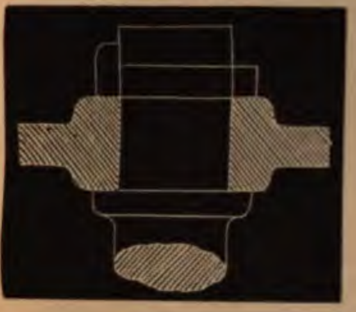

FIG. 25.—PISTON SECURED TO ROD WITH NUT.

FIG. 26.—PISTON SECURED TO ROD BY SCREWING ON.

FIG. 27.—STEAM AND EXHAUST VALVES AND PASSAGES.

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rule is to make it one-sixth the diameter of the piston. This is a rule which at any rate gives us strength enough, because, if we were calculating the strength of such a proportioned rod in the case of the cylinder 30 in. diameter, we should find the safe working pressure upon the piston rod = 4,480 × 19½ = 87,360 lb., whereas the pressure, as already worked out, upon cylinder cover only amounts to 42,360 lb., being barely one-half. But winding engines are not regular working machines, and the shock administered by throwing the steam against the piston when the engine is running at high speed must be very great, and a piston rod does well to be strong. In the engines under description it is not proposed to have back piston rods. The writer is quite satisfied from practical results with and without these back rods that they are not necessary for such sized engines as are used for winding. They have been removed from pistons 20 in., 24 in., 30 in., 32 in., and 36 in., and in every case the power of the engine has increased, and the wear of the cylinder has not increased. In a cylinder 36 in. diameter its removal increases the area on which steam can act nearly 30 square inches, and it avoids the friction of the back stuffing box and the back slide, and effects economy so far as the packing is concerned. Theory may urge that for all engines of all sizes rods are needed both behind and before. The writer can state that practice has shown that winding engines of the various sizes in most general use work better without them.

The Rose Bridge Collieries have shown very practically that back piston rods can be removed, not only without disadvantage, but with considerable benefit. The cylinders are 36 in. diameter, and about ten years ago more power was required and higher speed, the pit at which these engines are stationed having been sunk down to a depth of nearly half-a-mile, throwing of course a heavier load upon the engines, and necessitating a higher speed, if the same amount of work was to be done. The pressure of steam could not conveniently be increased, and the back piston rods were removed, thus increasing the effective area of the pistons, and lessening the friction. The power and speed were increased, and after ten years' actual experience Mr. John Bryham, the manager, reports

that the cylinders are not more worn upon the bottom now than formerly, and hundreds of pounds have been saved in packing. Certainly, in a matter of this kind an ounce of practice is better than a ton of theory. (See Appendix, Note C_2.)

Cylinders, Valves, and Valve Boxes.

Each cylinder to have four Cornish valve boxes, with covers and glands, and to be secured to cylinders with sixteen bolts; each stuffing box to have three gland bolts and nuts, and each cover to be secured to box by ten bolts, all 1 in. diameter, and each cylinder to be fitted with four brass Cornish valves, seatings, and 1¼ in. spindles, to be connected to lifting bars by links and regulating screw, and the spindles to be connected to valves by the ball-and-socket joint (see figs. 27 and 28). Many engineers construct winding engines with the slide valve, which in its ordinary condition is entirely unfitted for such a purpose, for two reasons: (1) its excessive friction, causing waste of power; (2) its unwieldiness and difficulty, almost approaching impossibility, of reversing with steam on. Some very elaborate experiments were made some years ago which proved that the ordinary unbalanced slide valve wasted almost one-eighth of an engine's power in friction. Many methods have been suggested, and some of them applied, for the purpose of lessening the friction, and some of these contrivances are commendable, others are complicated and waste as much steam by allowing it to pass the valve as the old valve did in friction. The most effectual remedy for the evils of the slide valve as applied to winding engines is not to tinker with them, but remove them absolutely by dispensing with the valve altogether. A Cornish, double beat, or equilibrium valve, by whichever name we like to call it, is not an exactly balanced valve—that is true; and it makes the engine more costly—that is also true. But the Cornish valve is a near approach to being balanced, and can be opened or closed, and put into any position with ease. And although it makes the engine more costly, the expense is not so great as the improvement effected. A very slight movement of the valve gives a large double opening for steam or for exhaust. Steam can therefore be admitted fully, or abso-

FIG. 28.—CORNISH VALVE AND SEATING.

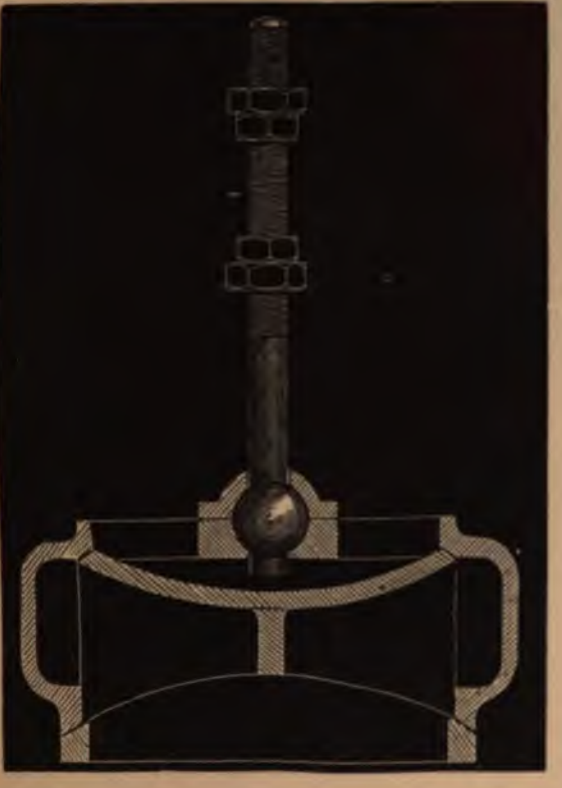

FIG. 29.—LINK MOTION.

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lutely shut off in very little time. There is some difficulty in keeping these valves tight, and often although tight when cold, they leak when hot. The remedy for this is to have the upper and lower seatings cast all in one piece, and cast at one melting, that is, with metal from the same ladle. By this means we ensure equal contraction and expansion between the valves and their seatings. These valves also, if attached to their spindles rigidly, do not always face all round their seatings, and an effectual remedy for this is the ball-and-socket connection shown in fig. 29, which gives a freedom to settle down. Valves should be large, and for winding engines especially, which want to do a lot of work in a little time, we need openings so that the steam can rush freely in to perform work, and when done with can rush as freely away. For engines working with an average piston speed of 600 ft. per minute, which is higher than the usual speed of winding engines, the steam passages and steam valves should have an area of one-tenth that of the cylinder, and the exhaust valves should have an area slightly greater. This would determine the steam valves 9½ in., and the exhaust 10 in. Engines for winding were introduced some years ago with the valve arrangements not as in the case described, one separate steam and one separate exhaust valve box and branch at each end of each cylinder, but having one steam and one exhaust both in one valve box at each end. So that the steam went in, and the exhaust passed out through the same thoroughfare. There really did not seem any benefit in this, and, on the other hand, it not only caused needless huddling together, but it was objectionable, inasmuch as the steam was constantly heating the exhaust passage, which is better cool, and the exhaust was constantly cooling the steam passage, which should be kept warm. (See Appendix, Note C_3.)

Valve Motion.

The valves to be worked by four eccentrics from wrought iron drag cranks worked by main crank pins. The valve motion comprises the reversing gear, the cams, the lifting bars, and the hand gear (see fig. 30). There is another method of working the eccentrics—namely, by

having a spur wheel upon the crank shaft working into another spur wheel equal in diameter upon a second shaft, on which are placed the eccentrics. The writer does not know what advantages are claimed for this arrangement, shown in fig. 30, but having had to do with a pair of winding engines with the appliance attached, he does know that the play of the teeth is objectionable as a noise, and eventually affects injuriously the working of the mechanism of the valves. There is still another way; when there is room upon the drum shaft the eccentrics are placed upon that shaft. But there is not always room for this, and it is not a convenient arrangement, because the eccentrics are in the way should any repairs want making to the drums, and the eccentrics, to fit upon a shaft 12 or 15 in. diameter, require to be so large that they become cumbersome, and the friction generated is objectionable. The drag crank arrangement (fig. 31) is the best; one little advantage it possesses is that the end of the drag crank shaft forms a convenient place for screwing in a small crank to give the requisite motion to an indicator. Winding engines do not usually work expansively. They must not be set to work permanently as expansive engines, because not only may they be needed to stop at, or start from, any point in the shaft when shaft examinations are being made, but at each winding, both for decking above ground and decking below, expansion is then out of the question. But arrangements have been made whereby a winding engine will automatically bring its expansion gear into operation when running as in a regular winding, and also automatically throw this expansion gear out of operation when speed is slackened or when decking is being done. Practical results must decide whether such appliances are correct or not. A winding engine is different from other engines. What we require in it is strength, security, speed, and simplicity, and economy is dearly obtained if opposed to any of these essentials. On the other hand, engines working without expansion at all are most wasteful. Working with full pressure of steam throughout the stroke means discharging into the atmosphere twice in each revolution a whole cylinder full of high-pressure steam which has done no work at all. Formerly, what an engine at a

colliery consumed in generating steam was thought nothing of, because it was really almost worthless fuel. But now it is different. At many collieries the fuel used at the boilers has been raised nearly 1,000 yards, and could be utilised for making the very best coke, so that every ton saved in generating steam is substantial benefit to the proprietor. Of course, with the usual valve motion of winding engines, as shown on fig. 29, steam can be worked expansively by bringing the handle into a notch nearer the centre. But this means that it must be adjusted by the engineman, who thinks, and probably he is right, that each winding he has to put the handle full over, then, when near the end of the journey, reverse, and afterwards manipulate the handle whilst decking, and that this represents work enough. Perhaps, also, the engine is none too large for its work, and wherever expansion comes in the same amount of work will require more engine power. If the engine needs all its power with full steam on all the way, as most of our engines do, there is an end of the matter. The writer considers the simplicity, power, and ease of working a winding engine of such first importance that whilst quite in favour of an efficient automatic expansion arrangement, he thinks with this, as with condensing arrangements, that if its addition made a winding engine complicated, it would be well to think once, twice, and even three times before adopting it. It is only fair to say that two attempts have been made recently, attended with considerable success, to overcome the difficulties and furnish the advantages of expansion arrangements. The Grange Iron Company have attached automatic expansion gear to the enormous winding engines at Silksworth Collieries, near Durham, at which establishment supremacy is claimed, and not without reason, for heavy loads and rapid winding. The engines are horizontal, and the cylinders are 48 inches diameter. Full steam is allowed upon the pistons at the commencement of the winding, and no expansion is effected until a certain speed is obtained. Beyond that speed the expansion increases, and at the highest velocity the steam is cut off at about one-fourth. The Uskside Company have introduced similar gear, or rather gear with similar objects to accom-

plish, into South Wales. The efforts of both these firms have been attended with considerable success, and not the least success has been the dispensing with complicated parts, and the introduction of machinery of a simpler kind, and not likely to get out of order.

Slides and Slide Blocks.

The bars to be of cast iron, and long enough to work a stroke of 5 ft., and to be planed on under surface of top bar, and upper surface of bottom bar, to compel a perfectly horizontal motion. The bars to be secured to foundation plate by a bolt (1½ in. diameter) at each end. Sometimes the slide blocks are shod with brass and the bottom slide bar made slightly V shape, and good results are obtained, because there are instances where the cast iron in the slide block and the cast iron in the bar will not work together, and both get grooved; but in the majority of cases everything goes on well with good well-planed cast iron blocks, of length not less than 18 in., working on cast iron bars with flat surfaces and both the upper and lower bars flanged. (See fig. 32.)

Connecting Rods.

To measure 15 ft. long from centre to centre, to have a diameter at each end of 5 in., and in the middle 7 in., and be curved in parabolic form. The fork end to be arranged to fit the cross-head journals, and the eye at the crank end to fit the crank pin, and to be fitted with the necessary brass steps, gibs, cotters, and regulating screws, as shown in figs. 33, 34, 35, and 36. A good proportion of length in a connecting rod is considered not less than three times the length of the stroke; and whilst the two ends have the same sectional area as the piston rod, the area in the middle should be double this.

Crank and Crank Pins.

The cranks to be of wrought iron, the large eye in section to measure 9 in. by 5 in., and the small eye to measure in section 7½ in. by 4 in., and between the eyes to average 15 in. by 5 in. The large eye to be bored 13 in. diameter and the small eye 5 in. Crank pins to measure

FIG. 30.—ECCENTRICS ON SECOND OR COUNTER SHAFT.

FIG 31.—ECCENTRICS WORKED BY DRAG CRANK.

FIG. 32.—SLIDE BLOCK AND SLIDES AND CROSSHEAD.

FIGS. 33 AND 34.—ELEVATION AND PLAN OF CRANK END OF CONNECTING ROD.

[*To face page* 24.]

in journals 5 in. diameter by 7½ in. long. The cranks to be bored to 1-16th of an inch less in diameter than the shaft, and heated and shrunk on, and to have a key 3 in. broad and 1½ in. thick, half into crank and half into shaft. The crank pin-hole to be also bored 1-32 of an inch less than crank pin, which is to be forced in with hydraulic pressure, and to have a key 2 in. broad and 1 in. deep. (See figs. 37 and 38.) Cast iron cranks are not nearly so common now, because there was a difficulty in keeping them tight. In putting them on, if the contraction was not enough they became slack, and if the contraction was too much they split. In keying them, if not driven tight enough they were slack, and if keyed up too hard they broke. Wrought iron possesses much higher tensile strain, and in every way is better. The strength of a crank pin can be calculated by assuming it as a cantilever 3¾ in. long and the weight applied at the end. The breaking strength of such a cantilever will be 3,500 × ¾ = 2,625 × 6 = 15,750 ÷ 3¾ = 4,200 × 5 = 21,000 × 5 = 105,000 × 5 = 525,000 lb. And the load that can come upon it is, area of piston 30 in. diameter = 706 × steam pressure 60 lb. = 42,360 lb., showing a margin between strength and pressure of 12½ to 1, even when full pressure of steam is on and the crank pin at rest.

Crank Shaft.

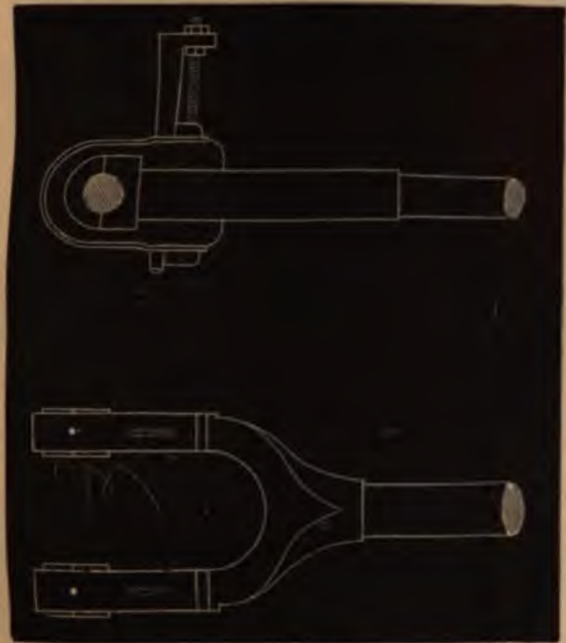
To be wrought iron and parallel throughout its length, except at journals, and turned to a diameter of 13 in. Key-beds, ¾ in. deep and 3 in. broad, to be planed through for cranks, &c., at right angles. The journals to measure 12 in. diameter by 24 in. long, the corners well rounded. (See figs. 39 and 40.) Crank shaft journals have a great weight to sustain, therefore will generate a good deal of friction, and should have bearings not over large in diameter, but long, so as to distribute the pressure. There are two strains to which crank shafts are exposed, namely, torsion, from pressure of piston upon crank pin, and transverse, from weight of drums. We have already ascertained that each piston has a pressure of 42,360 lb., which × length of crank, 2½ ft. = 105,900 lb. of twisting strain for engines. The twisting strength of a bar of good iron 1 in. diameter is 850 lb. applied at the end of a

lever 12 in. long, and this strength decreases with increase in length of lever, but increases with cube of diameter:— $850 \div 2\frac{1}{2} = 340$ lb. $\times 12 = 4{,}080 \times 12 = 48{,}960 \times 12 = 577{,}520$ lb., thus giving a margin of safety 6 to 1, when the full 60 lb. steam pressure is acting upon the piston. The other strain—namely, the transverse—is obtained in another way. Assume the length between necks 10 ft., then $3{,}500 \times \frac{3}{4} = 2{,}625 \div 10 = 262\frac{1}{2} \times 12 = 3{,}150 \times 12 = 37{,}800 \times 12 = 453{,}600$ showing the breaking transverse strain of 200 tons, where as probably the weight of drums will not exceed 20 tons, showing margin of safety as 10 to 1.

Crank Shaft Pedestals.

Nearly all who are connected with winding engines—those who make them and those who use them—are enamoured of what are known as angle pedestals. Sometimes they have their angle one way (as shown in fig. 41), and at other times the angle is the other way (as shown in fig. 42.) If angle pedestals are to be used, the writer prefers the latter, with the line of the rope at right angles to the cap, because in that case the pull is against a continuous surface, not with a joint in the middle. It may be urged that, arranged in this way, the strain is all upon the pedestal bolts; and so it is, and what does that matter. Take the pull upon each pedestal 10 tons, which is a very severe load, and suppose we have four bolts to each pedestal, each bolt 2 in. in diameter, these four bolts will give a solid sectional area of not less than 10 square inches, and this, reckoning a tensile strength of 20 tons per square inch, equals a total resisting strength of 200 tons, as against a load of 10 tons. But are angle pedestals necessary and are they an advantage? The power of the engine may for the moment be put out of the question, because it acts both forward and backward. If the pull upon the rope or upon both ropes were equal to the downward weight, then perhaps pedestals should be angled. But what is the case in this example? The maximum pull upon both ropes in middle of winding is $7\frac{1}{2}$ tons, and the total weight acting downwards, including drums, shaft, ropes on drums, brake rings, cranks, and connecting rods will not be less than 30 tons, and in some cases gets

Figs. 35 and 36.—Elevation and Plan of Fork end of Connecting Rod.



Figs. 37 and 38.—Side and End View of Crank Pin and Crank.

Figs. 39 and 40.—Bad Form and Correct Form of Journals.

Fig. 41.—Angle Pedestal with Cap facing the Pulley.

Fig. 42.—Angle Pedestal with Cap looking away from Pulley.

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up to 50 tons, showing that the downward weight is four times greater than angular force, so that really if the pedestal is to be angular at all, it should be not more than shown in fig. 43, which is so slight as to be not worth having; and as good a form of pedestal as any for crank shafts of winding engines is the ordinary straight-up pedestal. The fact is that the downward pressure is in all cases so much in excess of any other pressure that the pedestal in its construction may leave all other pressures out of consideration. Actual wear proves this.

Throttle Valve.

To be a Cornish valve 12 in. diameter, and, as mentioned in connection with cylinder valves, the seating and spindle and valve to be cast from same melting, to be fixed immediately under engineman, and to have attached the needful levers, bearings, handle, and quadrant, for holding valve open or closed or in any position. This valve should bear the same proportion to two cylinders as the valves already named bear to one. The important points of a throttle valve are—first, it should be tight when closed; second, it should allow sufficient flow of steam when open; third, it should be easy to open and close. There is no valve which fulfils all these requirements so well as the Cornish valve, and the advantage of the stipulation that it should be immediately under the engineman is that numerous levers and joints are avoided, and the action of opening and closing the valve is direct. (See fig. 44.)

Winding Indicator.

Every winding engine should have an indicator, not for ascertaining the power of the engine, but to indicate the position of the cages at every point of the winding. This should be worked from the drag crank by means of a worm and spur gearing, and should give motion to a finger moving round a dial,—this dial to be placed so that the engineman cannot fail to see it. The dial will have as many divisions as there are revolutions in a winding, and be arranged, whichever way the engine works, to strike a bell when the cage is three revolutions from the end of the journey, so as to warn the engineman to bring his engines

to a stand. Sometimes when the engineman is so placed that he cannot see his pit-bank, a working model is fixed in the engine-house, showing on a small scale the position of the ascending and descending cages. The only objection to such an arrangement is that it is not desirable that an engineman should be so placed that he cannot see his cage on reaching and leaving the surface.

Attached to some winding engines are indicators which record the number of windings. Some of these act well and record accurately, others are nearly always out of order, and make inaccurate records. These latter should simply be dispensed with, and those which work correctly applied. The plan of recording the number of windings by the engineman removing a peg from one hole to another after each winding is not reliable, and unworthy of our very excellent winding appliances. We ought to have attached to all winding machinery the needful mechanism for correctly reporting the number of journeys made in any day.

CHAPTER IV.

WINDING ENGINES.

Diagrams from non-Condensing Engines—Average Steam Pressure—Average Back Pressure—Average Effective Pressure—Speed of Piston—Horse-power of Engines—Holding-down Bolts—Construction—How Bed-plate is made Firm—Engine Pillars—Stone, Brick, Concrete—Length, Width, and Height—Comparative Cost—Bedding Foundation Plates—Planing Underside and dressing Pillar—Wedging up the Plates, and filling under with Cement—Advantages of Former—Cheapness of Latter—Engine-houses—Some Attention to Appearances—Walking Room at Sides—Drums should be Fenced—Plenty of Light—Entrance behind the Engineman—Beams across the Engine-house for Lifting—Separate Engines should have Separate Houses—Capstan Arrangements—Use of Capstan—Power of Capstan—Adaptability to either of Two Pits—Brakes—All-Round and Half-Round—Effective and non-Effective—Burns' Brake—Steam Brake—Steam putting Brake on and Dead Weight removing it Steam taking Brake off and Dead Weight putting it on—Defects of latter Arrangement—Best Arrangement of Steam Brake—Materials for Brakes—Winding Drums—Timber for Cage—Bolts, how let in—How Spiral Drums are made—The best Form of Winding Drum—Defects of all Winding Drums—Tail Rope under Cages—Advantages of Pulley in Sump—Garswood—Advantages of the Tail Rope—Strain upon the Capping—Counterbalance Chains at Burnley—Kœpe System—Its Principle—Its Advantages—Objections raised—Experience at Bestwood—Rules as to Winding Engines—Finding the Load a Pair of Engines will Start—Finding the Diameter of Cylinders for a certain Load—Approximate Period of a Winding—Useful Horse-power—Approximate Horse-power—Piston Speed of Winding Engines—Jules Havrez on Recent Improvements in Winding Machinery.

Diagrams from Winding Engines.

Several years ago the writer superintended the erection of a pair of winding engines built by Messrs. W. and J. Yates, of Blackburn, very much upon the lines of the engines described in Chapter III. The cylinders were 30 in., the stroke 5 ft., and the valves all upon the Cornish principle. They proved excellent in their working capabilities, and as diagrams were taken from them recently, it seems appropriate to introduce these diagrams here. They give the kind of figure usual with Lancashire engines. When first set to work the valve action was

such that a beautiful expansion curve was obtained, the steam being cut off at half stroke. But the engineman complained that he had not sufficient command of his engines. They worked well enough going ahead at a good speed, as in winding, but in decking they were not manageable, and for shaft examination were useless. The valve action was altered and the excellent curve of expansion disappeared, because steam was admitted practically the whole way. The boilers are within a few pipe lengths of the cylinders. The steam pipes immediately before reaching the cylinders are of increased diameter, to act as a kind of receiver, and the exhaust pipes close to the cylinders are also large. The exhaust is delivered into an old boiler, which is up-ended, and acts as a warmer, heating the feed to 212 degs. Fahr. A series of diagrams were taken from each end of each cylinder at various revolutions of winding. Two diagrams have been selected, taken at the seventh revolution, at which point the engine has got up to a good speed. Fig. 45 gives the diagram taken at the front end, and fig. 46 from back end of the same cylinder. The pressure of steam on gauge in engine house is 42 lb. In fig. 45, the pressures of steam upon the piston are, 38, 39, 39, 39, 39, 39, 39, 39, 38, 36 = a total of 385 = an average of 38·5 lb. The back pressures are, 18, 12, 9, 7, 6, 5, 5, 5, 5, 5 = a total of 77 = an average of 7·7 lb., giving an average effective pressure of 38·5 − 7·7 = 30·8 lb. per square inch upon the piston. The area of a 30 in. cylinder is 706·86 square inches − 19·63 square inches area of piston rod = an effective piston area of 687·23 square inches. The speed of the piston was 440 ft. per minute; therefore, 687·23 × 30·8 × 440 = 9,339,776·16 ÷ 33,000 = 283 horse-power of the front end of cylinder. In fig. 45, the pressures of steam are 39, 39, 39, 39, 39, 39, 39, 39, 38, 36 = a total of 386 = an average of 38·6 lb. The back pressures are 7, 5, 4, 4, 4, 4, 4, 4, 4, 4 = a total of 44 = an average of 4·4 lb., and thus rendering an average effective pressure upon the piston of 38·6 − 4·4 = 34·2 lb. per square inch. Having no back piston rod we get full area of piston = 706·86 square inches, and speed of piston was 400 ft. per second. Therefore, 34·2 × 706·86 × 400 = 9,669,844·8 ÷ 33,000 = 293 horse power at back end of cylinder. Taking

Fig. 43.—Principle of Angle Pedestals.

Fig. 44.—Throttle Valve.

Fig. 45.—Diagram from Front End of Cylinder.

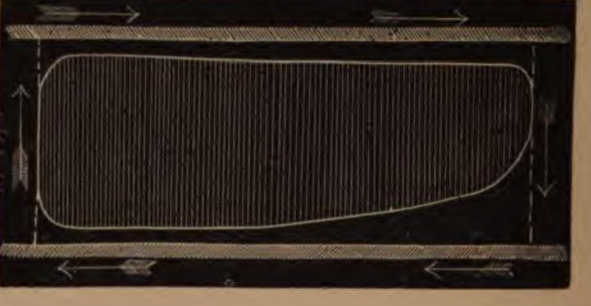


Fig. 46.—Diagram from Back End of Cylinder.

[To face page 31.]

these figures as showing the average power of the pair of engines, 283 + 293 = 576-horse power of engines, and taking the difference in pressure, viz., 42 lb. on gauge in engine house, as compared with the 60 lb. blowing-off pressure at boilers referred to in Chapter II., the results come out equally enough. A word or two of explanation as to the diagrams themselves, which were taken with a Hopkinson indicator. The writer has used this indicator for nine years, and prefers it to any other. The diagram fig. 46 calls for no remark, but fig. 45 shows that the exhaust valve does not open quickly enough, and the exhaust passages are throttled, hence the high back pressure. The steam valves and steam passages are right at both ends, as shown by the high initial pressure and its maintenance. To ascertain the work throughout a winding we should require a series of diagrams at every revolution, which with thirty or forty revolutions might mean nearly 200 figures. The two given are sufficient for the twofold purpose of this article, viz., first, to show the sort of diagram from such a pair of winding engines as has been described; second, to show how the horse-power is worked out from diagrams.

There will be other opportunities of speaking about the indicator and diagrams when pumping and fan engines are dealt with, because it is with such machinery that the indicator is a more useful instrument, and the diagrams taken are more interesting than with the winding engine. It will suffice to say here that to get pressure in the cylinder more nearly the pressure at the boilers we should have engines and boilers in close proximity, good large steam pipes, as free from bends as possible, and when bends are unavoidable have them of large sweep, and valves that will open quickly and afford a large thoroughfare.

The same remarks apply to the exhaust valves and pipes. Back pressure is inevitable in all engines, especially quick working winding engines, but fig. 46 shows that, even at a fair speed, if the exhaust arrangements are good, the back pressure need not be excessive.

Holding-down Bolts.

The object of these is not merely to prevent the engines sliding about with the working of machinery, because

the dead weight of the engines themselves is so much in excess of the load to be drawn that they would scarcely move if dependent upon their weight only; but the good working of engines requires that the parts shall be securely fitted to each other, and the whole fabric made absolutely unmovable, whatever shock may come upon substantial pillars; and the holding down bolts should be so distributed that the bed plates are held down with equal firmness throughout, and springing absolutely prevented. Good holding down bolts are made with a screw and two nuts at the bottom, and a screw with one nut at the top, and can be screwed up firmly and equally by placing a washer of pitch pine over the nuts at the bottom. The bolts themselves should nicely fill the holes in the bed plates and the plates or stones over the hand-holes, but as regards the engine pillars there is no advantage in having too little room in the holes. It is important that the bolts should be straight, not bent dog-legged to suit a crooked hole. In these bolts there is no weakening by cotter holes; the iron should be good and welds carefully made.

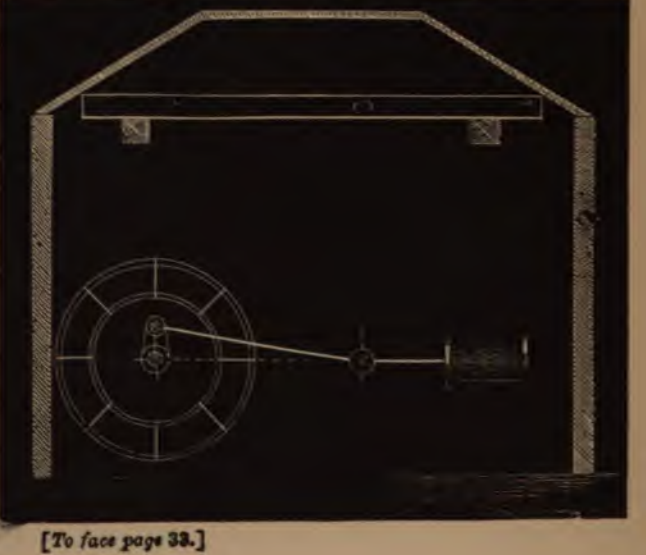
Engine Pillars.

These may be made of stone, as is mostly the case with vertical engines, or all of brick, or brick-casing with concrete interior, or entirely of concrete. The Bestwood collieries show excellent examples of engine pillars made absolutely of concrete. For vertical engines it is more important to have pillars that will resist shock than for horizontal. They are higher, and have less area of base, and are exposed to more pressure. But for horizontal engines, with pillars long enough and wide enough and deep enough, the material is not important if it will hold together. The length and width of pillars depend on length and width of engines. The depth is not settled so easily. We know the maximum pressure upon the pistons, and this would in no case necessitate such enormous pillars as are erected, representing a weight, in some cases, of more than 1,000 tons. We want height to give room for drums and brake wheels to work, and for the arrangement of steam pipes, brakes, and levers, &c. We often place capstan engines under the winding engines

Fig. 48.—Plan of a Concrete Pillar.

Fig. 47.—Section of a Concrete Pillar.

Fig. 49.—Beams for Lifting Parts of Engines.



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between the pillars. And it is found convenient to have the engine-house floor level with pit bank, which practically determines that the height of the engine pillars shall be the height of the pit bank. If it were not for considerations such as these the general height of engine pillars would be much less. A stone pillar will probably cost not much less than one shilling per cubic foot, whilst a brick pillar will not average half that amount, and a mixture of brick and concrete less again. So that we arrive at once at an idea of the high cost of an ashlar pillar containing some 200 cubic yards, as compared with a structure of brick alone or a mixture of brick and concrete. The writer has constructed a good many pillars for horizontal winding engines of 24, 30, and 36-in. diameter, as shown in figs. 47 and 48. Over each hand-hole for the full width of the pillar are placed cast-iron plates; at the top of the pillar there is one course of stone, about 2 ft. thick. The sides and ends are brought up with brickwork, the bolt holes are cased with brickwork, and a crosswall placed here and there to hold the casing well together. The interior is filled in with best furnace slag, put in layers about a foot thick, and all the crevices washed in with the same slag, but in the form of dust. In such pillars as these for engines with 36-in. cylinders, taking the solid contents of each pillar at 6,000 cubic feet, 1-9th was stone, 4-9ths brick, and 4-9ths concrete.

Bedding the plates on the pillars sometimes takes almost as long as erecting the engines. For large engines, as much as nine and ten weeks have been occupied in this way, but it ought not to be so. All engine-bed plates should be planed underneath—most of them are now—and all this planed under surface should be parallel with the centre line of engines, but it is not so—indeed, in some cases there is as much as an inch of difference. The process of bedding is a very simple one. The bed plates are packed upon the pillars and made level both ways. Then the mason does his pegging—that is, he finds the lowest place on the pillar, and having levelled a small space there he levels or pegs a large number of small places all over the pillar to correspond with this first one. The bed plates are raised up and the whole surface of the pillar

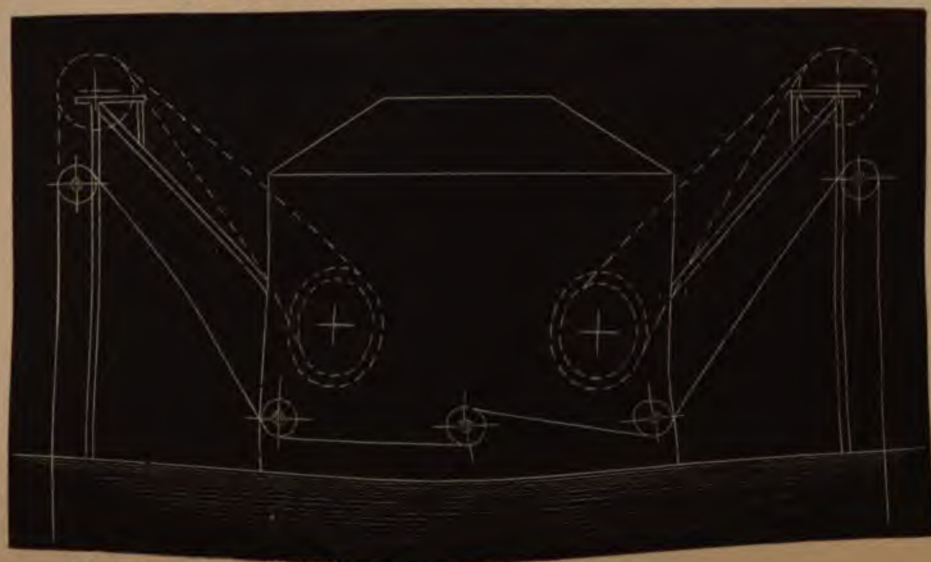
dressed off to the level of these pegged surfaces. This forms the first or roughing operation, and when this is done the bed plate is placed upon the pillar and rubbed, to show which places are "hard on." In this way, slowly and surely, the bed plates are made to fit over their entire surface. The operation may, with good stone and a true plate, be done soon, or with an uneven plate and hard stone it may occupy a long time. But, long or short, the work should be done well, and no engineer worth his salt will allow this bedding of engine plates to be badly done.

The expense attending this method of bedding engine plates has led to the adoption of a much more expeditious, although scarcely so effective a plan. No attempt is made to have the under side of bed plates level, they are taken in the rough and simply wedged up on the rough engine-bed to the requisite position and bolted down. Then all the crevices between the pillars and bed plate are carefully filled in either with borings or some other cement that will go hard and firm. This plan saves time and money, but compared with the older and slower and more costly plan is not so good.

Engine Houses.

Architecture has no place in these articles, but the writer has a strong opinion that colliery buildings might very well be made more pleasing to the eye without seriously increasing the cost. The space between engine pillars is regulated by the engines themselves, but not so the sides. There should be a clear walking-way between the engine and each wall, even past where the engineman stands. The drums should be fenced, not so much on account of the danger as to prevent the ropes throwing oil all over the house. Fencing machinery under the Mines Acts is carried to excess. It is all very proper fencing exposed machinery, but a winding-engine house is the engineman's castle; no one has any business to be in except himself, and to fence an engineman from his own engine is like fencing a man from the horse which he is riding. The windows should be arranged to give plenty of light without too much heat, and the engineman should be so situated that he can take in at a glance the pit bank and the whole of his engines. The entrance

Fig. 50.—Capstan Arrangement Adaptable for Two Pits.



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should be behind the engineman, so that a person entering during a winding does not take his attention. In every engine house there should be provision made for lifting in case of repairs to cylinders or crank shafts. The best plan is to throw a strong beam over the centre of the cylinders and another over the centre of the crank shaft, as shown in fig. 49. Cylinder covers have to come off, pistons have to be changed, shafts or cylinders may break, drums may need renewal, and therefore beams should be so placed that lifting tackle can be easily attached. If two distinct winding engines are in the same building they should be absolutely separated from each other by a wood partition or brick wall. Without saying that it is dangerous to have two separate winding engines in one house, it may be said that it is safer to give each winding engine its own building. The writer was connected with a colliery at which it had been thought good engineering practice to put the engine which worked the circular saw in the winding engine house close to the engineman. (See Appendix, Note D_1.)

Capstan Arrangements.

In addition to winding engines for a shaft a capstan is required. The winding engine may break or the cages may get fast in the shaft, and the capstan affords a ready means of doing what is needed in such cases. Or repairs in a shaft may be necessary, and whilst the winding engine raises and lowers the men and material the capstan holds and regulates the position of the scaffold. And when there are pumps in the shaft a capstan answers for drawing rods or changing buckets, or renewing stocks. Good capstan engines should really be winding engines on a small scale, with gearing attached. But whilst a winding engine has to be quick a capstan wants to be strong and slow. This is managed by having engines with small cylinders and the power multiplied by spur gearing. A pair of capstan engines, with 10-in. cylinders and 20-in. stroke, with gearing 20 to 1, and a drum not exceeding 6 ft. diameter will move as great a load as a pair of winding engines with 40-in. cylinders.

Fig. 50 shows a capstan arrangement of such a character that the same capstan does for either of two shafts.

Brakes.

These are required to keep the engine from getting into motion itself, and also to bring the engine to a stand more rapidly at any given point. There are brakes arranged to act over a long surface, sometimes half round the brake ring, and sometimes all round, thus, in this latter case, necessitating an upper as well as a lower strap. The amount of leverage and power with a foot brake under this arrangement is very limited, because on the one hand, not less than an inch of movement will suffice for the straps to clear the ring, and the traddle portion cannot travel more than 20 in. if the engineman is to work it conveniently. This gives a limit in the leverage of 20 to 1. But even with this kind of brake we may either have an inefficient brake, as shown in fig. 51, where there is nothing to take up the weight of the top strap when supposed to be "off," and the straps are so arranged as to have really little action upon the ring. Or, as shown in fig. 52, we may make the arrangement efficient by bringing the straps more upon the ring, and by easing the weight of the top strap. Brakes represented in figs. 51 and 52 have been, and still are very generally used, but latterly a new principle has been introduced. The object being to concentrate the action upon a short distance only, and thus enable relief to be obtained with slight movement, thus greatly increasing the amount of leverage. Fig. 53 shows the principle of Burns' brake, which has been successfully applied to powerful winding engines. There is no real objection to this concentration of the brake force, provided the ring is strong enough, and it is well known that the leading principle of friction asserts that the amount is independent of the extent of surface. Being able to increase the leverage from 20 to 1 to as high as 200 to 1 is an unquestionable advantage.

Many years ago—indeed, almost as soon as powerful winding engines became generally used—steam brakes were introduced, and the advantage is that we can have practically what power we please. Take the old form of brake, with leverage 20 to 1, and suppose the engineman exerting full force of $1\frac{1}{2}$ cwt. $=$ 30 cwt. applied to brake. Then take a steam brake with cylinder 12 in. diameter

FIG. 53.—BURN'S BRAKE ON.

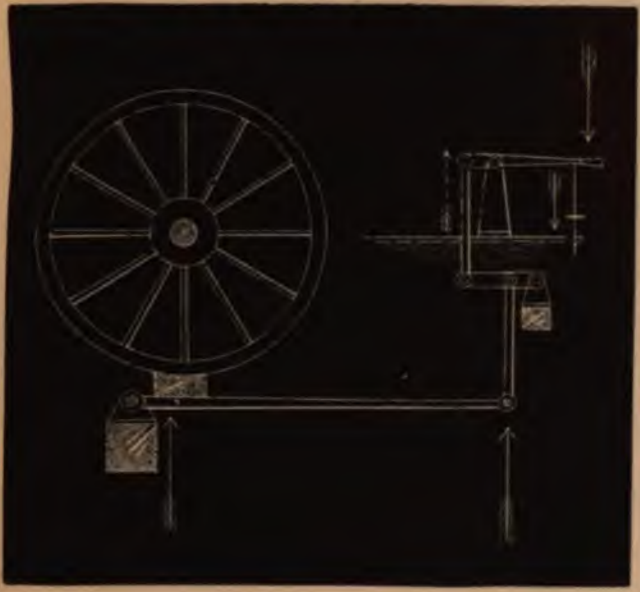


FIG. 51.—NON-EFFECTIVE ALL-ROUND BRAKE.

FIG. 52.—EFFECTIVE ALL-ROUND BRAKE.

FIG. 54.—PULLEY FOR BALANCE ROPE.

[To face page 36.]

and leverage 12 to 1, and pressure of steam 40 lb., we get a power upon the brake of $113 \times 40 = 4{,}520 \times 12 = 54{,}240$ lb. = nearly 500 cwt., and we could make it 500 tons by simply increasing the leverage and the area of cylinder. Steam brakes have been applied so that, a dead weight applied, the brake and steam pressure had to take it off. The idea was that no shutting steam off should prevent the brake from acting. This arrangement was wrong, because, first, a steam brake requires to be quick in action, and no dead weight can act so quickly as steam. Second, we must either fix the pressure which will take the brake off so low that the available pressure shall never fall below it, or we must often find ourselves in the dilemma of being unable to remove the brake. The best form of steam brake is one in which steam acts upon either side of the piston, and can remove or apply the brake at will. And to prevent tampering, a screw and wheel can be attached to lock the brake and keep it on, even if steam happens to be shut off. As to the material for brake surfaces, what is wanted is such a substance as will give a high co-efficient. When the straps act upon long surfaces hemp rope is suitable, working upon an iron ring. Also wrought iron has acted well upon timber, and even cast iron upon cast iron has been tried, and answered. In Burns' brake he uses short wood blocks with holes filled with sand.

Winding Drums.

Having in Chapter VIII. described and illustrated pretty nearly all the kinds of drums—namely, the cylindrical, the vertical, the conical, and the spiral, not much will need to be said about winding drums here. The cylindrical and the conical are made of cast-iron rings and wood lags. The timber should be cut into shape and wel dried before being used; otherwise, after being put on it will shrink and become distorted, and injure the rope in working. These drums are usually turned so as to enable the rope to work upon a true circle and it is well worth the expense. If the drum is very wide, that is 6 ft. or 8 ft., it is well to have a middle ring. The lags should be thick enough to resist the transverse pressure brought to bear upon them, and also to allow for the

rope wearing into the lags, and should be able to allow the drum to be returned. The bolts which secure the lags to the rings should be well let in to be out of the way of the rope. A rope will work well enough on either wood or iron, but any one surface should be either all wood or all iron. Spiral drums are made in various ways, first, with wood lags and the spiral grooves turned in the lags; second, of wrought-iron plates and a sufficient thickness of wood to allow the groove to be made; third, of wrought-iron plates and the spiral formed by laying on iron specially grooved for the rope to work in. The serious defect of all these drums is their enormous weight and size. Their width necessitates the engines being placed far apart, adding to the expense both of engines and buildings in which they are placed. Their weight adds enormously to the first cost of the engines and it is so much useless dead weight to be put in motion each winding and to be brought to a stand.

The best of all winding drums far away is the spiral, but drums in themselves are an evil, and scarcely a necessary one. There really seems no good reason why the "Kœpe system," or some modification of it, should not take the place of winding drums. Winding engines at best are, and will be, extravagant engines, but dispensing with so unwieldly a moving part as the drum would save money at the first, and save fuel afterwards.

Tail Rope under Cages.

Where an engine is fitted with a cylindrical drum, has a clear shaft, and a sufficiently deep sump, good results are obtained by placing a tail or balance rope under the cages. But with any other drum, and when the shaft is full of pipes, &c., and when the sump is not sufficiently deep, balance ropes are not advisable. The writer was surprised, when first made acquainted with this principle, to find no pulley in the sump. It did seem that part of the appliance was wanting, and it almost appears now that the pulley on which the rope in the sump shall work is necessary and can easily be applied.

Mr. C. F. Clark, of the Garswood Coal and Iron Co., has been kind enough to furnish particulars, from which

Fig. 55.—Balance Rope Arrangement.

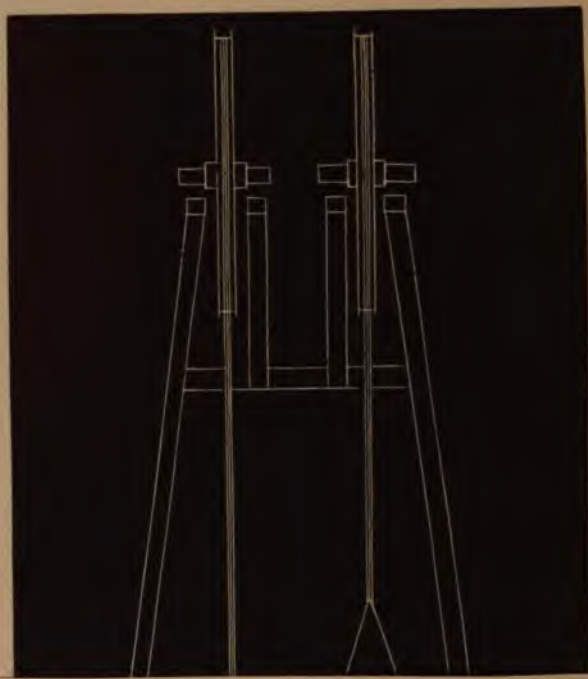


fig. 54 is taken, illustrative of the pulley arrangement applied on his works. The pulley, under ordinary circumstances is stationary, but is free to move up or down, as may be required, and it is very effective in keeping the balance rope right. We all understand the advantage of the tail rope—it makes the load uniform. But we must remember that the tail rope adds very seriously to a somewhat tender part of the winding rope—namely, the capping. With the usual winding arrangement the load upon the capping is the cage and tubs and fuel, and this load is constant. But with the tail-rope arrangement we add to the load upon the capping the entire weight of the tail-rope, which may amount to as much as the load itself. The writer made some experiments a year or two ago with and without the tail-rope, and found an unquestionable gain with it. The engines started their load with a lower pressure of steam, and a winding could be made with the same pressure of steam in considerably less time. But the particular shaft was not convenient for the appliance. Water had to be wound very often with a tank swung under the cage, and there were a great many horsetrees and landings and pipes in the shaft which made it scarcely safe to have a tail-rope dangling about. Fig. 55 shows the general arrangement of the balance rope and the pulley in the sump.

In the Burnley district what are known as counterbalance chains have been introduced instead of counterbalance ropes. The objection to ropes is that when no pulley is provided in the sump they form loops and become dangerous, and even when pulleys are used they must necessarily be small in diameter, and unless a rope is made specially pliable it is not likely to have a long life.

Chains can be made any weight, need no pulley in the sump, form no loops, and work very steadily. At Townley Collieries worked by Brooks and Pickup, the most satisfactory results have been obtained from well-made counterbalance chains of good material.

The Kœpe system of colliery winding dispenses altogether with winding drums and substitutes a pulley. One winding rope answers for, and is attached to both cages, instead of having a separate rope for each. This rope having a cage at each end simply passes about half

round an ordinarily constructed V pulley on the crank shaft. The balance rope under the cages is used in connection with the Kœpe system. The advantages claimed for the arrangement are manifold. First, massive winding drums are abolished, thus avoiding the enormous weight to start and stop each winding. Second, the pair of engines can be brought closer together, thus making the crank shaft shorter. Third, a smaller engine house is required. Fourth, only one rope is actually used for winding. Fifth, the rope always coils round exactly the same diameter. Sixth, the rope always works in the same line. Seventh, the load is exactly uniform throughout the winding. Eighth, a smaller pair of engines are equal to the work. Objections have been taken to the arrangement that the rope is liable to slip upon the drum pulley, if the rope breaks the two cages fall down the pit, and the difficulty in re-capping. However, the Kœpe system has been fairly tried at the Bestwood Collieries and has been successful. There are two pits exactly the same depth, and raising the same load in equal times, the steam from the engines coming from the same range of boilers. The Kœpe engines have 30 in. cylinders, and 5½ ft. stroke. The non-Kœpe engines have 36 in. cylinders, and 6 ft. stroke. Such a result is certainly encouraging for the advocates of the Kœpe system of colliery winding. (See Appendix, Note D_2.)

Rules as to Winding Engines.

1. To find the load which a given pair of engines will start. The engines 20 in. diameter by 40 in. stroke, the drum 12 ft. diameter, and the steam pressure at boilers 50 lb.

Multiply the area of one cylinder by the pressure of steam and twice the length of stroke. Divide this by circumference of drum and deduct one-third for friction, &c. The result is the load the engines can start :—$314 \times 50 = 15{,}700 \times 80 = 1{,}256{,}000$. The circumference is 12 ft. = 452 in. $1{,}256{,}000 \div 452 = 2{,}778 - \frac{1}{3}$ or $926 = 1{,}852$ lb., the load.

N.B.—The load referred to in this and next rule comprises rope and fuel, becauses cage and tubs are supposed to balance each other.

2. Knowing the load and the diameter of drum and the length of stroke and the pressure of steam, to find the area and diameter of cylinders. The drum 15 ft., the stroke 6 ft., the steam pressure 60 lb., and the load 7 tons = 15,680 lbs.

Multiply the load by the circumference of the drum and add one-half for friction, &c. Divide this by the steam pressure multiplied by twice the length of stroke and the result is the area of the cylinder:—15,680 × 47 = 736,960 + ½ or 368,480 = 1,105,440. 60 × 12 = 720. 1,105,440 ÷ 720 = 1,535 square inches, area of piston. 1,535 ÷ ·7854 = 1,954. Square root of 1,954 = 44¼ in., which will be the diameter of cylinder.

3. To find the period of a winding approximately.

Reckon the piston to travel at an average velocity ot 400 ft. per minute, and divide this by twice the length of the stroke, and multiply by circumference of the drum. This gives speed of cage in feet per minute, and divide depth of pit by this, and the result gives period of a winding. Drum 47 ft. circumference, stroke 6 ft., depth of pit 600 yards = 1,800 ft. = 400 ÷ 12 = 33·33 × 47 = 1566·5; and 1800 ÷ 1566·5 = 1·15 minutes, being about 1¼ minutes.

4. To find the useful horse-power during a winding.

Multiply the depth of pit by weight of fuel raised, and divide this by period in minutes occupied in winding, and divide again by 33,000. Fuel, 2 tons, = 4,480 lb., depth 1,500 ft., period of winding ⅚ths of a minute; 4480 + 1500 = 6,720,000 ÷ ⅚ = 8,064,000 ÷ 33,000 = 244-horse power.

5. To find the approximate horse-power exerted by a pair of winding engines during a winding.

Multiply area of both cylinders by two-thirds of boiler pressure of steam and by 400, and divide by 33,000. Cylinders 30 in. diameter = 706 square inches, boiler pressure 60 lb., two-thirds of which is 40; 706 × 2 = 1412 × 40 = 56480 × 400 = 22,592,000 ÷ 33,000 = 685-horse power.

6. To ascertain the piston speed of a winding engine.

Divide the windings into periods of three revolutions each. Let two persons take alternately the time in seconds which each three revolutions occupy. Take the average from these as follows:—Suppose there are thirty

revolutions divided into ten periods, three revolutions each, the time occupied in seconds comes out 9, 7, 5, 3, 2, 2, 2, 3, 6, 9, = 48 seconds for the whole winding. Suppose the stroke 5 ft. × 2 = 10 × 30 = 300 piston feet in 48 seconds, and 300 × 60 = 18,000 ÷ 48 = 375 piston feet per minute.

The chapters on winding appliances can scarcely better close than by mentioning a work entitled "Recent Improvements in Winding Machinery," written by Jules Havrez, a continental mining engineer, and ably translated into English by R. F. Martin. It has not been written exactly for the class to whom the present book is specially addressed, but it contains some good drawings, and, for the ripe scholar, much useful information.

CHAPTER V.

THE WORK OF WINDING ENGINES.

Winding Engines at Pearson and Knowles' Collieries—General Arrangement of Winding Appliances—Size of Engines—Size and Lift of Valves—Size of Steam and Exhaust Pipes—Number and Size of Boilers—Feed Warmer—Effect of Feed Warmer—Deficiency of Boiler Power—Number really required—Possible Horse-power of Engines—Size of Drum—Size of Headgear Pulleys—Distance from Pulley to Drum—Depth of Pit—Load of Coal raised each Winding—Size and weight of Ropes—Gross Load at Bottom—Period of a Winding—Time of Decking—Weight of Coal raised per hour—Number of Revolutions each Winding—Revolutions with Steam on—Revolutions during which Brake is applied—Diagram of Power exerted, Load raised, and Speed attained—Average Piston Speed—Average Speed of Cage—Average Effective Pressure of Steam throughout the Winding—Suggested Application of the Balance Rope under the Cages.

There are few better examples of high-pressure direct-acting non-condensing horizontal winding engines than the pair working at the Moss Pits of the Pearson and Knowles Coal and Iron Company, designed by, and erected under the superintendence of Mr. Israel Knowles, general manager of the collieries. Mr. Knowles has been good enough not only to allow diagrams to be taken from the engines, but also placed his officials at the service ot, and personally rendered every assistance to the writer in obtaining correct particulars of what the engines are doing and can do. Figs. 56 and 57 give a fair representation of the general winding arrangements in elevation and plan. The engines are of course coupled at right angles, and have cylinders 40 in. diameter, with a stroke of 7 ft. The engines are fitted with Cornish valves, the diameter for steam being 10 in., the full lift $\frac{3}{4}$ in. and the diameter for exhaust being 11 in., with $\frac{13}{16}$ in. full lift. The main steam pipes are 13 in. diameter, and the main exhaust pipes 15 in. diameter. Steam is supplied from five Lancashire boilers, each 28 ft. long by 7 ft. diameter, worked at a blowing-off pressure of 60 lb. per square inch. The distance that the steam has to travel is not

considerable, and there are no unnecessary bends in either the steam or the exhaust range. The exhaust is delivered into a large feed warmer, about 7 ft. diameter, of the kind described and illustrated in other chapters. The exhaust simply enters at the bottom and passes out through a chimney at the top. When this class of warmers was first introduced, it was thought necessary to place a grid across the warmer just above the exhaust inlet, and on this grid was piled a large quantity of big boulder stones, the idea being to extract from the exhaust as much of its heat as possible. The cold feed-water was delivered at the top and had to pass in between these stones. With winding engines working anything like constantly no stones are required. A grid is placed here and there in the height of the warmer; the exhaust and feed-water meet and do all that is needed. The efficiency of this feed-warmer in this particular case is proved in a twofold manner—first, the feed is heated to the boiling point; second, diagrams taken from the engines at various strokes show inconsiderable back pressure at any time, and about the middle of the back stroke almost *nil*.

According to the rules already laid down in previous chapters on winding engines—viz., assuming a piston speed averaging 400 ft. per minute throughout the winding, and an effective pressure of steam upon the piston of 40 lb. per square inch, these engines would develop 1,200 horse power, and require all the steam that six Lancashire boilers of the size named would generate. But there are only five boilers, and other engines of considerable dimensions draw steam from them, and the result is the engines do not develop 1,200-horse power, because they do not obtain nearly so high an effective piston pressure as 40 lb. per square inch.

As Mr. Knowles wisely puts it, present arrangements accomplish such work as is necessary, and the present is not a time for adding two more boilers, at a cost of £1,000. At some future time more coal will have to be raised, a sufficient number of boilers will be added, and the engines will then reach the 1,200-horse power of which they are capable. The drum is 25 ft. diameter at the largest point, it being a few inches conical, not with any idea of compensation, but for enabling the round winding ropes to

Fig. 58.—Diagram of Power and Load.

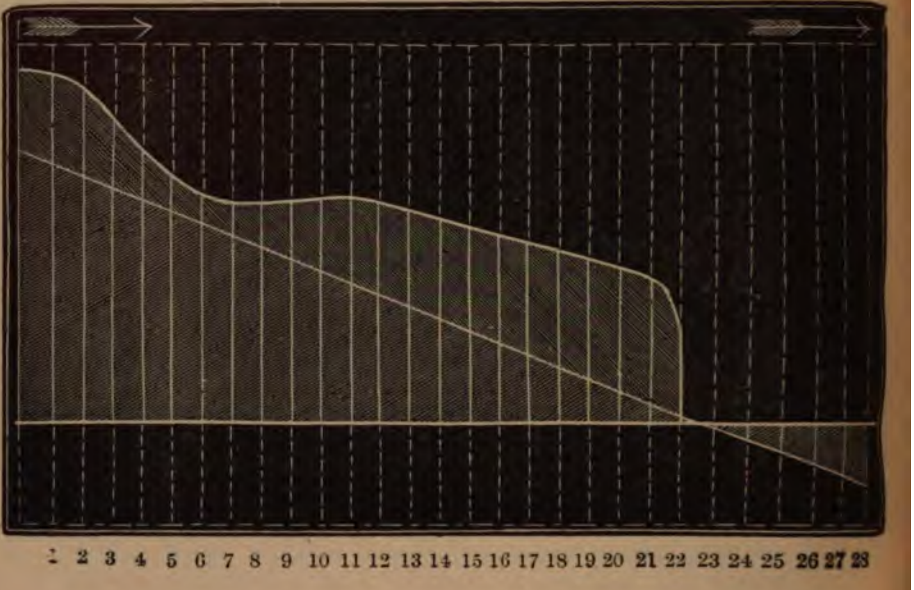
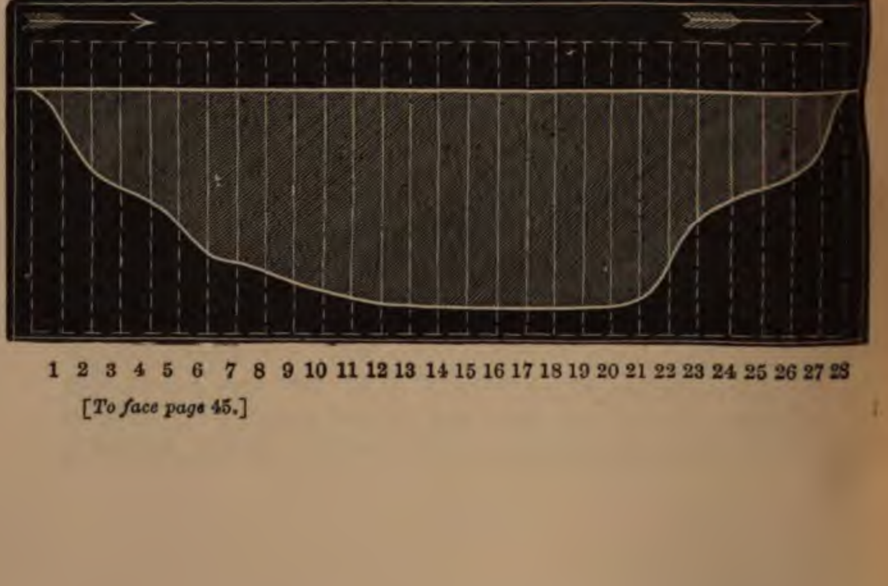


Fig. 59.—Diagram of Speed.



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coil upon it more regularly than they would if the drum were cylindrical. Very good results are obtained from the winding ropes, for several reasons: first, the drum is large; second, the headgear pulleys are a good size, being 18 ft. diameter; third, there is next to no side friction, because the distance from the centre of the pulley to the centre of the drum is nearly 90 ft. This distance should never be less than 90 ft., and very excellent results have been obtained with even a greater distance, whilst winding ropes are soon ruined with short distances. (See Appendix, Note E.)

As will be seen from fig. 57, the line of the back stays of the headgear is as nearly correct with the line of the ropes as possible. The depth of the pit is 715 yards, the weight of fuel raised each winding is about two tons, the ropes measure 4¼ in. circumference, and add to the load to be started from bottom three tons, making a gross load to start of five tons. The period of a winding is sixty-five seconds, and the time occupied in decking is forty-five seconds, making the total period for raising and decking one minute and fifty seconds. This represents about sixty-five tons of fuel per hour. The engines make twenty-eight revolutions to a winding, twenty-two of which are performed with steam on. At the end of the twenty-second revolution steam is shut off, and the engineman brings the engines gradually to a stand by the action of his foot-brake during the remaining six revolutions without steam upon either side of the piston. Diagrams are taken during each of the twenty-two strokes performed with steam, and the general results are shown on fig. 58, which gives the load and power at every revolution, and on fig. 59, which shows the speed of the piston at each stroke during the winding. The figures nearly explain themselves, and not much in the way of explanatory remarks is needed. The load to start from the bottom is five tons, and this regularly diminishes to the end of the twenty-third stroke, at which point there is an exact balance, and for the last five revolutions the descending cage has an increasing advantage. The effective pressure of steam upon the piston is 30 lb. per square inch during the first revolution, and diminishes to 14 lb. per square inch during the twenty-second revolution; the

speed of the first revolution is 120 piston feet per minute, which increases to the end of the twelfth stroke, at which point the speed has attained its maximum—namely, 560 ft. per minute, which is maintained to the end of the twenty-first revolution, from which point the speed slackens. The average piston speed per minute during the winding is 360 ft., and the average speed of the cage 1,980 ft. per minute, and the maximum speed of the cage during a winding is 3,140 ft. per minute. The average effective pressure throughout the twenty-two revolutions of the winding is 20 lb., and the average piston speed during the winding has already been stated—360 ft. per minute —which gives an average horse-power exerted 530, as compared with 1,200 horse-power, which these engines could exert if the steam supply were sufficient. A ready means of increasing the efficiency of these engines is found in the balance rope. At present the load to start is five tons, of which three-fifths represents weight of rope. The balance rope under the cages would remove this, and reduce the load at starting to two tons. The load at present varies from five tons during first revolution, and gradually diminishes till at the end of the twenty-third revolution the load has disappeared, and for the remaining five revolutions the load is increasingly in favour of the descending cage. The balance rope would remove this inequality, and make the load uniform throughout the winding. Less steam would be required to start, the start could be more easily made, and a winding would occupy less time.

CHAPTER VI.

THE WINDING ENGINE AT MONKWEARMOUTH

Depth of Monkwearmouth—Weight of Coal raised per Day—Number of Persons raised and lowered each Day—Weight of Coal each Winding—Period of a Winding—Gross Load at Bottom each Winding—Method of Counterbalancing—Clumsy but Effective—Size of Cylinder—Length of Stroke—Number and Size of Boilers—Pressure of Steam—Size of Condenser and Air Pump—Size of Drums—Number of Revolutions—Average Piston Speed—Average Speed of Rope—Diagrams from Top and Bottom of Cylinder—Average Steam Pressure in Cylinder—Average Vacuum in Condenser—Consumption of Coal per indicated Horse Power per Hour—Engine has worked Night and Day for Seven Years—Remarkable Example amongst Winding Engines.

A SINGLE vertical engine is scarcely what would be recommended now-a-days for colliery winding, horizontal engines in pairs being much more generally adopted, but there are very few winding engines in the world, horizontal or vertical, single or coupled, that give a better account of themselves than this single vertical direct-acting condensing winding engine at the collieries of the Wearmouth Coal Company, Sunderland.

The pit is 600 yards deep, thereabouts, and as 1,800 tons of coal have been raised, and over 1,200 men and boys lowered and raised in twenty hours, the output per hour will not be less than 100 tons. Sixty-seven hundredweight of coals are raised each winding, which occupies one and a-half minutes. The cage and tubs and winding ropes will amount to not less than 11¾ tons, comprising rope 90 cwt., cage 35 cwt., tubs 43 cwt., and coals 67 cwt. The tubs and the cage on each side balance each other, leaving only the coal and the rope to be dealt with. And as by a method of counterbalancing with chains the rope is to a large extent balanced, there is practically only the coal to raise. The engine has a cylinder 68 in. diameter, being equal to a pair of coupled engines with cylinders 48 in. diameter, and the stroke is 7 ft. Steam is supplied from four cylindrical externally-fired boilers, each measuring 40 ft. long and 7 ft. diameter,

having Jucke's furnaces attached, which in this instance give good results as to uniform and economical firing and consumption of smoke. The steam is never allowed to rise above 20 lb. per square inch, and the usual working pressure upon the steam gauge in the engine-house is 17 lb. The engine works condensing, and the air pump is 3 ft. 10 in. diameter, and the condenser 4 ft. 4 in.

Fig. 60 gives a general representation of the engine. The drums, which are vertical, measure about 21 ft. diameter on the smallest coil, and twenty-eight revolutions are made in each winding. This, reckoning one and a-half minutes to a winding, gives an average speed for rope of 1,200 ft. per minute, and an average piston speed of 260 ft. per minute. The ropes are so excessively heavy, amounting to more than the weight of coal, that the engine unassisted could not start. With round ropes on cylindrical drums we balance with a tail-rope under the cages. With round ropes on spiral drums the diameters of first and last coils are so proportioned that they balance each other. But with flat ropes neither of these appliances will answer, and a method almost peculiar to the North of England is in operation, and does its work well. Heavy chains coil upon a small drum upon the drum shaft. These heavy chains pass over a pulley upon a head-gear, and pass down a shallow pit. When the engine starts its load from the bottom, these heavy chains just communicate between the bottom of the shallow pit and the small drum. As the winding goes on the heavy chains coil off the small drum and accumulate at the bottom of the shallow pit, till midway in the winding all the chain has coiled off, and for the remainder of the winding has to be drawn up and coiled upon the drum—the principle being that the ascending cage is assisted during the first half of the ascent and retarded during the latter half. It will be easy to see that in this way the weight of the rope can be counterbalanced, leaving practically nothing for the winding engine to do but raise the coal and overcome friction.

Fig. 61 shows the arrangement of counterbalancing with chains, and like the engine itself looks cumbersome, and is perhaps not the arrangement one would recommend, but it answers well, and seems about as good an appliance

as need be for flat ropes. The counterbalance chains at this colliery weigh 6 tons, and coil upon a drum 3½ ft. diameter. Diagrams were taken from the top and bottom of the cylinder at about the average speed of the engine—namely, 260 piston feet per minute. The steam on the engine-house gauge was 17 lb., and the vacuum was 26 in.

Figs. 62 and 63 show the diagrams, which the engineer pleads "are not so good as could be wished, owing to the piston wearing slack, having had to work night and day for seven or eight years, and therefore steam passes." There is nothing to be ashamed of in the diagrams, although no doubt if the engine could be overhauled and put into new working order much better figures would come out. Steam seems to be admitted all through the stroke, and diminishes in pressure. The top diagrams, with 17 lb. on steam gauge, and 26 in. vacuum, show an average steam pressure of 10 lb., and an average vacuum of 8 lb., being an effective absolute pressure of 18 lb. The bottom diagrams, also with 17 lb. on steam gauge and 26 in. vacuum, give the same steam pressure—namely, 10 lb., and rather better vacuum—namely, 10 lb. Taking both top and bottom the average steam pressure is 10 lb., and the average vacuum 9 lb., making a total average effective pressure of 19 lb. This, at a piston speed of 260 ft. per minute, and in a steam cylinder 68 in. diameter = 3,600 square inches area, allowing for piston rod, will represent horse-power as follows:—$3600 \times 19 = 68400 \times 260 = 17784000 \div 33000 = 539$ horse-power, which comes marvellously near the indicated horse-power of the high-pressure winding engines referred to in a previous article. But in this case 100 tons per hour are raised from 600 yards, as compared with 65 tons per hour raised from 700 yards, being as four to three in work done in favour of the condensing engine. And in this case the steam blows off at the boilers at 20 lb. above the atmosphere = 35 lb. absolute, as compared with a blowing-off pressure of 60 lbs. above the atmosphere = 75 pounds absolute, being again more than two to one in favour of the condensing engine in the matter of steam used. These are remarkable results—two winding engines exerting about the same horse-power, and one works with one-half the steam and does one-third more work. The engineer at Wear-

mouth Colliery calculates that the winding engines consume 6 lb. of coal per indicated horse-power, and this, although, as shown by the diagrams, the engine—from its continuous night and day work, extending over seven years—is far from being in good order. Theoretically, we ought to get an indicated horse-power per hour from ¼ pound of average coal. Practically, from good continuous working engines, we do not get an indicated horse power per hour from 2 pounds of coal. But the ordinary winding engine seldom accomplishes the work with less than 10 pounds. In the figures 62 and 63, showing diagrams, the central horizontal line represents atmospheric pressure—the central shaded portion shows the diagram of work; the upper shaded portion shows the difference between pressure on the steam gauge in the engine house and the pressure upon the piston; the lower shaded portion shows the back pressure—that is, the difference between absolute vacuum and the vacuum upon the piston; the top horizontal line represents pressure upon steam gauge, and bottom horizontal line represents absolute vacuum.

The winding engine at Monkwearmouth was of especial interest to the writer, inasmuch as it was the first condensing engine for winding with which he became practically acquainted. It does not run so quickly as the non-condensing engine, which would make a winding of this depth, 600 yards, in half the time, 45 seconds. But to raise from this depth nearly 2,000 tons in 20 hours, and change over a thousand men and boys, with steam never exceeding 20 pounds pressure supplied from four boilers, places the Monkwearmouth engine in the very front rank for economy and quantity of work. (See Appendix, Note F.)

CHAPTER VII.

AN EFFICIENT BRAKE FOR WINDING OR HAULING.

Bickershaw Collieries—Good Example of Modern Colliery Enterprise—Aggregate Daily Output—Means of Ventilation—Number of Boilers and Excellence of Equipment—Winding Engines—Depth of Pits—Load of Coals each Winding—Form of Drums and Ropes—Makers of Machinery—Walker Brothers, Pagefield, Wigan—Haulage from Surface—Air-compressing Engines—Necessity for Powerful Brake during Sinking—Disastrous Results if Brake fails—Patent Hand and Foot Brake of Thomas Burns—Its Principle—Difference from Ordinary Brakes—Objections to and Defects of Ordinary Brakes—Burns' Brake costs Less at First and Less for Repairs—No Jerking—No undue Exertion required on part of Engineman—Enormous Force put on Gradually—Material and Construction of Brake Blocks—Length of Wear—Adjusting Screw—Adaptability of Handles—Extensive Application—Opinion of Enginemen—Objections to Steam Brakes—Objects of all Good Brakes for Hauling or Winding Drums—Burns' Brake a Practical Success.

The Bickershaw Collieries at Leigh, Lancashire, afford a good example of modern colliery enterprise. Seven years ago their site was a green field, and at the present time several large pits are at work, with an aggregate output of 1,500 tons per day, and extensions are being made which in a few months will enable this amount to be doubled. (See Appendix, Note G_1.) Ventilation is effected by one Guibal fan, 46 ft. diameter, arranged to take air on both sides, and another similar fan is in course of erection. There are two magnificent ranges of Lancashire boilers of eight in each range, enclosed in substantial buildings. These boilers are about as efficiently equipped as any in the district. The damper arrangements are such that they can be regulated from the front, and each boiler is fitted with one Cowburn dead-weight safety valve, which prevents the pressure rising above the blowing-off point, and another Hopkinson low-water safety-valve, which opens and allows all the steam to escape in case the water sinks below the proper level. The writer was pleased to hear

on the occasion of his visit that no ashes were allowed to remain in contact with the front of the boilers, and that consequently no slacking of ashes, with its consequent injurious influences, resulted there. The winding engines are horizontal, in pairs, the largest being 7 ft. stroke and 36 in. cylinders. The deepest shaft is something over 600 yards, and 66 cwt. of coals are raised at one winding. The ropes are all round, and the drums cylindrical. Nearly the whole of the machinery has been made and erected by Messrs. Walker Brothers, of Pagefield Iron-works, Wigan, and does them infinite credit. At present all the haulage is worked by ropes taken from the surface, but it is in contemplation to erect large air-compressing engines, so as to give power to hauling engines or pumping engines, as may be required underground. When the second Guibal fan (and whatever ventilation may be adopted at collieries, whether furnace or mechanical, no harm can result from having it sufficient or efficient) and the proposed air-compressing engines are at work, the Bickershaw Collieries will be in possession of large examples of nearly all the classes of colliery mechanical appliances. It was a matter of considerable importance to have during the sinking of these deep shafts a simple and efficient brake. For regular winding operations with two ropes balancing each other the efficiency of a brake is not so thoroughly tested, but in sinking with one rope, without any balance, where the descending load of men or materials must be under the exclusive control of the brake, this is of the highest importance, because accident through the engine running away would not only have disastrous consequences to the men in the descending hoppitt, but the large number of men employed in the shaft would be in a dangerous position. No class of men have proved themselves more equal to emergencies than colliery engineers, and it was so at Bickershaw. Mr. Thomas Burns, the engineer, determined that a simple and efficient brake should be introduced, and his appliance, duly patented in his name, forms the subject of this chapter. It was incidentally mentioned in the article on winding engines, but its importance deserves more detailed notice. The brake is shown in figs. 64 and 65. The ordinary brake appliances

Figs. 64 and 65.—Elevation and Plan of Burns' Brake.

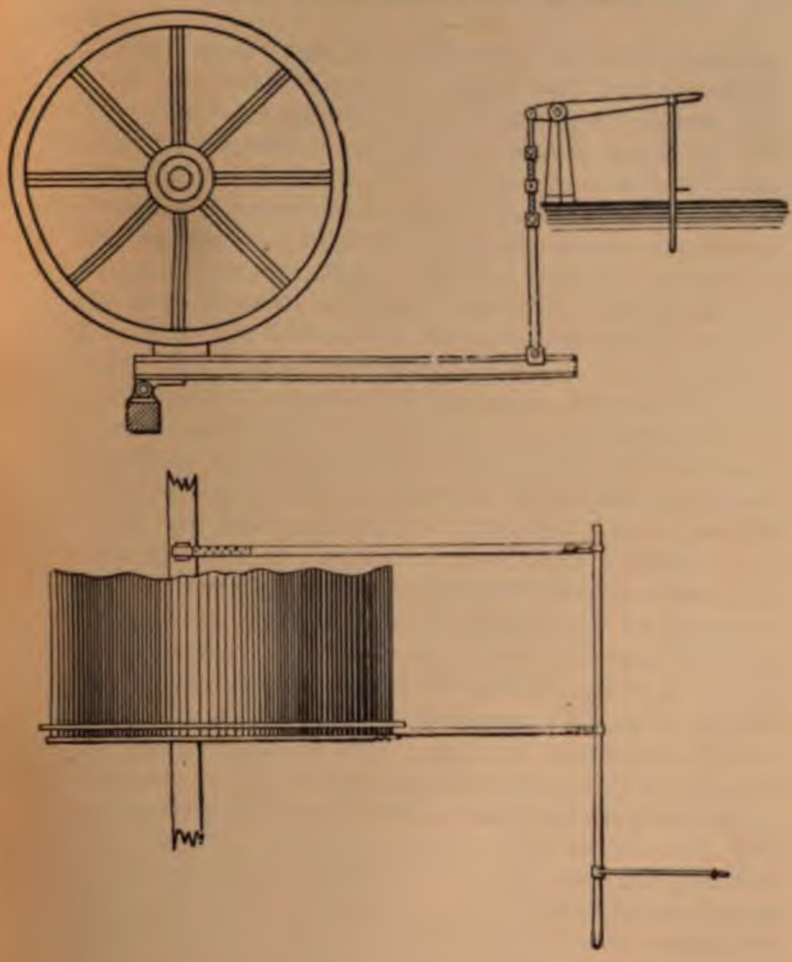

Fig. 66.—Timber Block for Burns' Brake.

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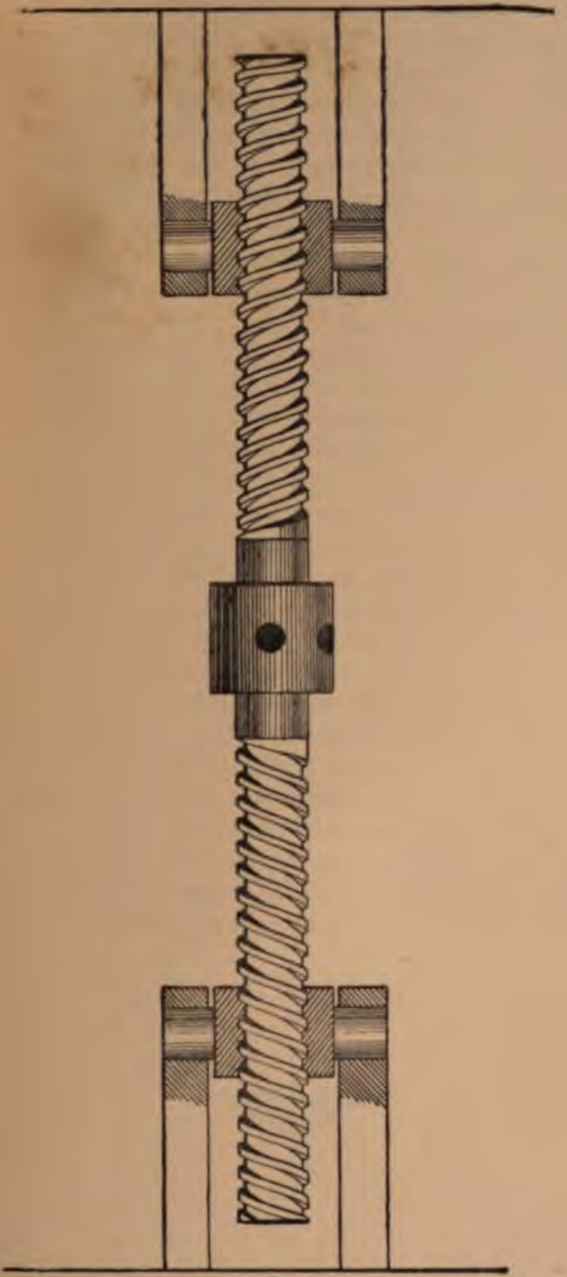
for winding and hauling engines are the foot brake and steam brake with straps passing at least half round the drum-ring. As regards the foot brake, it answers well where the amount of work is light, that is, either the load is insignificant or the ropes and cages are nearly balanced. But when much power is required it is useless, because on the one hand it is limited in leverage, because a sufficient amount of travel must be afforded to let the strap clear the drum, and this practically limits the leverage to 1 in 20. It is thus limited, as the movement of the engineman's foot cannot conveniently exceed 20 in., and if 1 in. of travel is allowed for the brake-strap the leverage cannot exceed 20 to 1. On the other hand, the power is limited to the pressure which the engineman can conveniently exert, which, as a regular thing, will not exceed 1 cwt. So that we have 1 cwt. of power, a leverage of 20 to 1—and this means, with a co-efficient of friction one-half, a force of 10 cwt. upon the brake-drum; whereas, in many cases, the pull upon the drum will be greatly in excess of this. What we mean by the pull upon the drum is the actual load at the end of the rope, which, of course, acts at the circumference of the drum. Then, as regards the steam brake, it can be made to any power, dependent only on the leverage, the diameter of cylinders, and the pressure of steam. But a steam brake is practically a steam engine, and is expensive—first in its cost, and second in its consumption of steam; and the power of the steam brake can hardly be varied—it is either all on or all off, and acts suddenly, doing injury to the machinery. Again, both these foot and steam brakes have upon their straps hemp rope, which is costly and soon wears away. In deep sinkings a length of brake rope will, in many cases, not keep good for more than a week, and time is occupied in its renewal.

Mr. Burns contends that with his brake there is less first cost, and less cost in working. He uses no steam; the brake can be worked without any undue exertion by the engineman, and is so constructed that either an enormous force or a very slight one can be put on, and it is done without any sudden jerk. Any brake arrangement in which the power is applied by the foot must be gradual in its action. The principle of the old form of brakes is

to apply the rubbing surface as long as possible, in some cases all round a circumference amounting to over 60 ft. Theory says friction is not dependent upon surface; practice proves that to some extent friction does depend upon surface in contact. The real fact is that with reasonably small bearing as much friction is obtained as on a large surface. In Burns' brake the power is applied on a small part only of the lower surface, not exceeding 2 ft. The result is, instead of requiring a movement of at least an inch to enable the brake to come off, the slightest movement will accomplish this, and the leverage can be proportionately increased. This is so, as with a strap half round or all round a vertical fall or rise must be considerable to effect clearance, whereas with a brake block acting on the bottom, almost a shade of movement gives perfect clearance. Instead of iron straps and hemp ropes, the Burns' brake has a block of pitch pine, about 2 ft. long by 1 ft. deep by 6 in. thick, being exactly one cubic foot, and holes are bored into this block vertically from the top, and these holes filled with sand, which keeps the brake surface clean and free from greasy matter. One of these blocks will wear three months, and can be renewed in a few minutes. These brakes will easily give a leverage of 200 to 1, which affords a retarding force of five tons, and a separate brake can be attached to each brake ring, thus multiplying the power to any extent. By means of the adjusting screws, shown on fig. 67, the brake can be tightened or slackened by the engineman himself in a few seconds, without leaving the engine-house. The handles can be adapted to any position of the engineman.

This Burns' brake has been in operation for years, and is applied to all the winding and hauling engines at the Bickershaw Collieries, and has never failed. It firmly holds the heaviest load upon the largest engines, and the enginemen, who, after all, are the best judges, having had large experience with all kinds of brakes, unanimously pronounce this the most easy for them and the most efficient they have used. One enthusiastic engineman said, as compared with any other brake he had tried, it was as good as sixpence a day to him. The appliance has already, although a comparatively new invention, had an extensive adoption, being in use in various parts of England and

FIG. 67.—ADJUSTING SCREW FOR BURNS' BRAKE.



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abroad. An eminent firm of engineers have an arrangement with the patentee whereby they attach the brake to all the winding engines they make, and in every case it has given entire satisfaction. Some time ago the writer had to do with the sinking of two large shafts, over 600 yards deep, with one flat rope in each, and although no accident resulted, the brake appliances were a source of some anxiety. (See Appendix, Note G_2.) Working with one heavy rope and sending down large hoppitts of bricks and other materials was a serious tax upon the ordinary foot brake, and the wear of hemp rope was something very serious. Steam brakes may be all right in case of regular winding to stop a loaded cage suddenly in a case of emergency, but for lowering either men or material in a sinking pit are not so convenient as a foot brake. And in any case steam brakes are only good because they are powerful. No one will argue that a steam brake should be used in preference to a foot brake if the latter gives equal power. In Burns' brake we get the power of the steam brake combined with the economy and convenience of the foot brake. The object of a brake on a winding engine is three-fold—namely, first, to stop speedily the moving machinery; second, to do this without jerking; third, to effectively hold in any position the heaviest load that can be put on the cage. Tested in this manner Burns' brake is practically a perfect one, and deserves the success it has already attained by its general adoption, and deserves more—namely adoption at those collieries to which its success has not yet penetrated.

CHAPTER VIII.

COLLIERY ROPES.

Manufacture of Ropes—Lack of Information—Materials used—Hemp Iron, and Steel—Charcoal Iron—Crucible Steel—Bessemer Steel—Plough Steel—Advantages of Steel—Varieties of Steel—Form of Rope—Round and Flat—Advantages of Round Ropes—Grooved Iron on Spira Drums—Cylindrical Drums—Conical Drums—How Flat Ropes shoul Work—Position of Drum and Pulley—Vertical Drums—Suggeste Improvements—Injurious results from Loose Packing—Injury to Rop passing through Rim of Drum—Securing Ropes round Drum Shaft—Coil Friction, how calculated—Arguments for frequent Re-capping—Distance from Drum to Pulley for Round Ropes and Flat—Over-loadin Ropes—Diameter of Pulleys—Forms of Part of Pulleys where Rop works—Importance of Greasing Ropes—Methods of Greasing—Almond's Machine for Cleaning and Greasing—Injury to Rop standing in Furnace Shaft—Ropes should be proportioned to thei Work—Hauling Ropes should not rub Floor or Roof, but should work o Pulleys—Inspection of Ropes Real and not Superficial—When are Rope Safe and when Unsafe ?—Objections of a Rope changing its Size o Drum—Forms of Headgear Pulleys—For Round Ropes and for Flat—Taper Ropes—Their Theoretical Advantages—Their Practical Defect —Rope Records in Office and Engine-house—Comparative Cost o Ropes—Springs between Rope and Cage—Safe Working Load of Rope of Round and Flat, Charcoal Iron, Crucible Steel, and Plough Steel—Weight and Size of Ropes—Margin of Safety between Working Loa and Breaking Strain—Extra Weight of Iron Cores.

It is not proposed to say anything in this article abou the manufacture of ropes. If some good Samarita amongst our eminent rope makers would address th engineering public on the various methods of manufactur and the qualities of materials used, a very great amount o useful information would be imparted, and rope makers b none the worse. Engineers, whether connected with gas, sewerage, railways, or collieries, and whether civil mechanical, or mining, freely at their meetings explain t their fellows the principles and details of their specia works and occupations, and good instead of harm results The same remark holds good with iron and steel manu-facturers, and it is not at all unreasonable to hope that er long the public may be favoured with a good treatise o rope manufacture from an eminent maker. (See Appendix, Note H_1.)

The writer does propose to speak as to one or two kinds of ropes extensively used for hauling and for winding at collieries, and also give a few descriptions and suggestions resulting from experience extending over a generation in the use of ropes.

The materials in use are hemp, iron, and steel. The former is now only adopted for more than usually shallow mines, where not much length of rope is needed, and where, consequently, the weight of the rope itself is not considerable.

To show the absurdity, almost amounting to impossibility, of using hemp ropes for deep workings of modern times one simple illustration will suffice. Taking a pit 600 yards deep, and a maximum load, including cage, tubs and fuel, of 5 tons, we should require a hemp rope measuring 11 in. circumference, and weighing 15 lb. per yard. This would represent a total weight of rope to be raised and lowered exceeding 4 tons, and if we add the weight of rope itself to the strain upon it, we should want a hemp rope weighing not less than 21 lb. per yard, being a total weight of rope alone of nearly 6 tons, thus in excess of the cage, tubs and fuel combined. Hemp, therefore, is out of the question for winding, and as to hauling is not worthy of consideration.

Iron ropes are much used in many parts of the United Kingdom, and with a good many proprietors and engineers are more popular than steel—in fact they will not use steel. Their argument is that iron is much more reliable, will wear longer, and whilst more pliable for passing round pulleys, is not nearly so treacherous, and does not fail so unexpectedly. The writer has had some experience with ropes of iron and ropes of steel, and has obtained good results with both, but in his opinion steel is the superior material for winding and hauling ropes. No doubt there have been cases where ropes made of steel wire have proved treacherous, and after a remarkably short life have been condemned. But because a steel rope here and there does badly, we ought not to condemn all ropes of steel. Steel ropes have worked badly, and proved treacherous, and in so far as they have given way without warning, or even after warning, it does not show that steel is bad generally, but may be bad,

and iron ropes are just as likely to fail unexpectedly, and do fail as often unexpectedly as steel ropes, and whenever this occurs we should deal severely with the guilty party, the wire maker — whether iron or steel.

The enormous advantages of steel over iron in ropes are—(1), there is less weight to be moved up and down each winding by the engines; (2), the rope has a greater strength with a less size, and can pass round pulleys and drums with less injury. Taking the same example as before, a depth of 600 yards, and a maximum load of 5 tons, the following results come out:—A steel rope would measure 3½ in. circumference, and would weigh 5¼ lb. per yard, or a total weight for the 600 yards of rope of 30 cwt. An iron rope under the same conditions as to depth and load would measure 4¼ in. circumference, and would weigh 8 lb. per yard, or a total weight for the 600 yards of rope of 43 cwt., an excess in weight exceeding 40 per cent. The greatest impediment as regards steel, and what is a fruitful cause of bewilderment to purchasers, is the numerous qualities of steel used for ropes. We have Bessemer, crucible, patent and plough, and as if these in themselves were not sufficient, there are various qualities of each. To give steel ropes a fair chance we should adopt the same lines as using iron, viz., have the best steel and under favourable circumstances. There are cases in which good wire wears little better than bad. But with good appliances, and careful management during use, the higher qualities of steel will more than repay their extra expense. Plough steel wire possesses a tensile strength equal to 120 tons per square inch, and is largely and successfully used for deep windings and heavy haulage.

Having discussed the question of material, there comes perhaps the most important part of all, namely, the form of rope. Shall it be round or flat? For haulage no other than the round rope is thought of, but for winding the flat rope is largely used; and this does not apply simply to old collieries, established thirty or forty years ago, but flat ropes have been applied, and are being applied, to new and extensive concerns of the most modern character. The supposed advantages of the flat rope are—(1), there is no tendency to twist; (2), it involves an absolutely safe

winding drum, in which the rope cannot possibly slip. But is this so? The writer knows from actual and troublesome experience that flat ropes will twist. In some cases flat ropes have been used in sinking pits, and so serious, even amounting to actual danger, has been the amount of twisting that temporary conductor arrangements have had to be made. Then, it is said there can be no slipping of the rope when flat ropes and vertical drums are used. Even if this were correct, it is not a feature peculiar to this kind of rope and this kind of drum. But, as a matter of fact, flat ropes can slip in verticals, and as a matter within the writer's own experience on several occasions flat ropes in verticals have actually slipped, and winding ropes have been ruined. The arms of the vertical either wear too wide, or open out, or both, and the rope slips and fastens itself edgewise between the lower coils and one arm, as shown in fig. 68.

Having thus criticised the supposed advantages of flat winding ropes, what are the attendant disadvantages? The following statement is based upon careful calculation, as regards comparative weight and cost, and upon experience as to the comparative length of life. Taking the old illustration once again, a depth of 600 yards, and a maximum load of five tons, a round steel rope will weigh 5½ lb. per yard, or a total of 30 cwt., and the flat steel rope under the same conditions will weigh 9 lb. per yard, or a total of 48 cwt. Whatever might be the cost of the round steel rope, the flat steel rope, calculated for exactly the same load, would almost certainly cost twice as much; and the round rope will, with similarly fair usage in each case, work nearly twice as long. A rough-and-ready practical way of putting the comparison is to say that a flat rope costs twice as much, lasts only half as long, and throws double the weight upon the engines. This means that the pecuniary advantage of round as against flat is something like four to one. About the very best winding rope arrangement that can be adopted is the round steel rope, working upon grooved iron specially made to fit the rope and placed upon a spiral drum, as shown in fig. 69. A round rope has not a fair chance of life when working upon a cylindrical drum, as in fig. 70, nor when upon a plain ungrooved conical drum, fig. 71, because of side friction.

But with a drum fitted as shown in fig. 69, with the specially grooved iron, steel round ropes wear for many years. Although one may, for the reasons advanced, be strongly in favour of round ropes, still flat ropes for winding are extensively used, and one object of this chapter is to show how these ropes, bad as they are in themselves, are made worse by misuse. To explain this, it is necessary at first to show, as is here done in figs. 72 and 73, the difference between right and wrong in the relations of drums and headgear pulleys. A flat rope is in this particular respect a sensitive bit ot goods. If the drum and headgear pulley be exactly in line, and the rope connecting them absolutely straight, then an equal amount of strain is exerted across the rope, and all goes well; but if the drum and the headgear pulley are not absolutely in line, and if the line of the rope changes on leaving the pulley or entering the drum, then the strain becomes unequal—too much is thrown upon one edge of the rope, and no strain at all upon the other edge, and an exceedingly short life may be predicted for a flat winding-rope working under such circumstances. It is also essential that the freedom of the rope between the vertical arms should be restricted, and thus compel the coils to form truly one upon another. What is required, of course, is not to give the rope insufficient room to work. The rope must have a width in which to work slightly greater than its own width, but care must be taken from time to time to see that the arms are kept right, and not allowed to go wrong. (See figs. 74 and 75.)

Too much play can be formed between the arms, first, by the wearing away of the inner surface under the action of the rope. This can be effectually prevented as shown in fig. 76, by casing or lining the inside of each arm with half-round iron about 2 in. broad. If the screws which secure this half-round iron to the arm are nicely counter-sunk, no damage whatever is done upon the winding-rope, and the wearing action upon the arm ceases. A second cause of the dangerous amount of clearance between the arms is the side action of the rope forcing them out. The remedy for this is to have the arms of good timber, not less than 4 in. deep, and to strengthen them still further, attach to the back of each a wrought-iron strap 1 in. thick,

Fig. 77. Fig. 78. Fig. 79.

Back Side Front
of Vertical Arm.

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and as wide as the arm. This arrangement is shown in figs. 77, 78, and 79, and together with the lining of half-round iron already referred to, keeps the rope working in a sufficient space, and prevents that space from dangerously increasing. Flat ropes also are liable to serious injuries from the rough, rude manner in which they are used by enginemen and others in charge of them. It is not easy keeping what is technically termed the "chase" right, especially when flat ropes are new, because they keep settling down in position, and "come out."

To correct this irregularity, the engineman keeps some ugly pieces of hemp rope handy, and when needed puts a length of one or two yards in, under the rope, just at the point where the load starts from the bottom. The result is, the rope not only does not work upon a solid base, but instead of coiling upon a true circle, has to mount a series of small steps. The writer has, in cases where flat ropes have come under his charge, laid down regulations that such loose pieces of packing shall not be used. In putting a new rope on, a length of rope equal to circumference of drum, and as wide as the rope, and tapering from nothing at one end to the full thickness of rope at the other end is first placed upon the bare block, and the rope coiled upon it. A number of lengths, each equal to circumference of drum of this oak packing of various thicknesses are kept on hand. It can easily be calculated, knowing the number of revolutions to a winding, what thickness of packing is needed to make a difference of three, or six, or nine, or twelve, or fifteen feet. Whatever thickness may be needed, a whole circumference of it is put on, and as near the drum-block as can be. The result is, the winding rope coils upon a true circle, and upon a firm foundation. It can be granted freely that this method causes more trouble, and therefore adds to the expense. But is it worth the extra trouble, and is it worth the extra expense? Suppose two flat winding ropes cost when new £300, and wear two years. Suppose the regulations referred to above add another year to life, which means a saving of £50 per year, and causes an extra expense, perhaps of £10, thus effecting a clear economy of £40 per year. Nearly all drums are so made that the rope, in passing through the rim into the interior to be

secured, makes a very sharp curve. It seems strange that whilst we all object to passing ropes round small pulleys, we almost invariably, in putting the rope into the drum, make a curve of almost no radius. This is bad enough in a round rope, but with a flat rope is much worse, because the whole weight of the load and pressure of the coils is exerted upon this particular point. Figs. 80 and 81 show what may be considered a right and a wrong way of passing the rope into the drum. So serious is the effect of this sharp bend upon a winding-rope that it has actually broken in consequence. Where such sharp curves do exist in drums it is good practice when putting them on to heat and thus soften the rope at this point. This causes loss of strength certainly, but as not much tensile strain is felt there, this will be no detriment.

Whilst dealing with this part of our subject it may be well to mention the securing ropes to drum shafts, and to anyone possessing a knowledge of the principle of coil friction it does seem amusing the number of coils round the drum, the number of coils round the shaft, and the number of strong clamms to make things safe. So little need is there for all this security that when the load is starting from the bottom the rope round the shaft has scarcely an ounce of strain upon it, and can be shifted about quite easily. With one coil round either the drum or the shaft, a pull of 1 lb. will resist a weight of 9 lb., if two coils $9 \times 9 = 81$, if three coils $9 \times 9 \times 9 = 729$, and so on, multiplying the former result by 9 for each additional coil. So that this almost marvellous result comes out. Suppose when the load starts from the bottom we have three coils upon the drum and three coils upon the shaft, making six coils in all, a pull of half-an-ounce will overcome the resistance from a load of 10 tons. And yet we put on clamms strong enough and numerous enough to support the whole weight of a pit shaft acting directly. But securing the rope at the other end of the cage is a very different matter. We have no coil friction there, and must have security. Figs. 82 and 83 show two methods of forming this attachment. The capping system would seem to be the best—it occupies less space, does the rope less injury, looks the best, and if done by a good and careful workman is very safe and endurable. In some

collieries a rule is laid down that capping shall be renewed at intervals not exceeding three months, but such an arrangement is neither desirable or necessary. There are pits where, owing to some peculiarities in winding arrangement, a capping is liable to much and frequent injury, and where this is so, it should be renewed much oftener than each three months. But there are other pits where the capping is in no way liable to special injury, and is as good at the end of a year as when new. To renew a capping under such circumstances each three months is simply to cause expense and inconvenience, without at all increasing safety.

An argument for re-capping is to overcome the injury received by the rope always lying in the same position upon the pulley when the engine is stopped. This will only apply with effect during the night, or at a meal hour, and as the engineman can place his cages in any position he chooses there is not much force in that argument. The damage done to cappings is not so much by the load upon them, but is caused by the buckling just at the top of the capping where the rigid capping ends and the flexible rope begins. This buckling is due to the repeated lowering and raising of the cage, and the slack rope during decking. An effectual remedy for this is to dispense with the catches on which the cage rests while the tubs are changed, and in this way always maintain a tight rope. This practice is successfully adopted at Burnley and at Bridgewater, and the engineman can actually assist the unloading of the cage by placing it slightly above the pit bank, and assist the loading by placing it slightly below.

In laying out colliery arrangements the position of the pit and the engine house to each other depend, to some extent, upon the kind of rope decided upon. If a round rope, whether to work upon a cylindrical, conical, or spiral drum, the distance should be considerable; 30 yards from headgear pulley to drum has been found to answer well. But if a flat rope, working upon verticals, advantage is derived by lessening the distance, and bringing them as close as may be convenient to other arrangements—15 to 20 yards from headgear pulley to drum gives satisfactory results.

Before drawing these remarks on ropes to a conclusion something should be said against the practice which prevails, more or less, of having excessive loads. No rope should have a maximum load greater than the safe working strain laid down by the manufacturer. There is, of course, in all cases a large margin between the breaking strain and the working load, and on account of this it is supposed that no risk is run by putting on a load considerably in excess of the maker's safe working strain. This sort of thing is a mistake in every way, and is a false economy, sometimes leading to disastrous consequences. A rope overloaded is unduly strained, and although showing no defect at the moment, will some day give way without warning. The maker gets blamed, and his rope is denounced as a bad one, when the fault is that neither the rope nor the manufacturer have had fair play.

In the proportioning of drums and pulleys it is well to keep them as large as the engines will allow. It could be proved, but is so self-evident as to need no proof, that those ropes wear the best that run upon the largest drums and pulleys; with cylindrical drums or vertical drums the diameter should agree with that of the pulley. Of late years an excellent system has grown up of having head-gear pulleys, whether for round ropes or flat, turned in the part where the rope works. But too often there is not sufficient metal in the rim, and what there is is somewhat too yielding. The result is the rope wears a groove which goes on increasing in depth until the rope goes through the metal, and a new pulley is needed. There is no reason why pulleys should not be so constructed in this respect as to wear as long as the pulley will hold together. (See figs. 84 and 85.) Ropes would work for a longer period if properly and regularly greased. But sometimes this operation is performed and sometimes neglected, and when it is performed the greasing is not thorough. The time required to grease long winding ropes led the writer, some years ago, to try the plan sketched in fig. 86. A sort of trough is formed in two pieces of timber which clamm the rope but loosely. The rope is surrounded by waste, and this waste well saturated with oil enough to oil the whole length. The engine is started, a winding is made, the rope passes through these clamms and trough and

Fig. 84.—Section of Pulley Rim for Round Rope.

Fig. 85.—Section of Pulley Rim for Flat Rope.

Fig. 86.—Method of Greasing Winding Ropes.

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waste and oil, and the rope is supposed to be thoroughly greased, but it is not. The plan is good enough for saving time, but it is not nearly so good a plan as using brushes. If making use of brushes takes longer and costs more, still it pays for all this in the increased wear obtained from the rope. Great care should be taken to prevent a winding rope remaining longer than is absolutely necessary in a furnace shaft, especially opposite the furnace itself. Some years ago there was a case of a rope having been standing in a hot furnace shaft for a considerable time, and was afterwards raised, and, of course, coiled upon the drum. On lowering it down again some time after the rope was found broken. The heat of the shaft had lengthened it, and on reaching the surface contraction set in with cooling, and being held tightly upon the drum the contraction broke the rope.

A north country engineer, Mr. C. W. Almond, of Monkwearmouth, recently brought out an invention for effectively and quickly cleaning and oiling winding ropes. The winding rope passes between two friction rollers, which grip it with sufficient tightness that the moving of the rope causes these rollers to revolve, and their revolution gives motion to brushes, one of which cleans and the other does the oiling. The few pounds which such a machine would cost would be more than refunded in the oil saved, and the additional life given to one large winding rope.

In proportioning ropes for endless haulage, it is easy, with a little care and calculation, to avoid either excess or deficiency of strength. Excess adds to cost, increases weight to move, and hampers work. Deficiency allows accidents and prevents work. The maximum load that will be put upon the rope at one time should be ascertained, and from this we determine a safe working strain, and so get the dimensions of the rope. In direct haulage, and tail-rope haulage, it is not at all necessary for the efficiency of the haulage that the rope should wear channels either on the floor or in the roof; nor is it essential that the rope should have to wear grooves on a lot of worse than useless pulleys, which do not revolve. No wonder ropes soon wear away and new ones are so frequently required when ten times more injury is done upon them

in this way than in the actual loads they draw. Every engineer should insist upon having for winding and for hauling ropes of good material and good workmanship; but it is of equal importance, and rests with himself to see that the appliances are good, the load not excessive, and the daily supervision of an efficient character. These principles put in practice, and adhered to, would lessen the expense of ropes very considerably.

The inspection of ropes, as well as other colliery machinery, now ordered by Act of Parliament, is liable to drift into mere formal looking at things. It is not necessary that very elaborate examinations of everything should be made daily; such would occupy the whole day, and no work could be done; but in addition to the more ordinary inspections of every day, a real thorough overhauling should be made once in each week. The writer's idea of good rope inspection is—after having it well cleaned of grease and dirt, passing it slowly through the hands of the inspector, who is most diligently watching and feeling for broken wires and split stitches. In a rope of considerable length a very large number of broken wires will be found without the rope needing to be condemned. The point is—Are there many broken wires all in one place? And are the other wires much worn? Also places will be found where the stitches have given way, and still the rope be allowed to work. The danger is when the rope is split for a great length, and has become, instead of one homogeneous structure, a mere collection of strings hanging loosely together. Sometimes a defective place is discovered between the drum and the pulley, just as the load starts from the bottom. This is caused no doubt by the strain being greater at this point than any other in the whole length of the rope, and the engines are not started to work with sufficient steadiness, but allowed to make a jerk, which has a ruinous effect upon a rope. When such a defect has been discovered, and the rope otherwise in good working order, it has been taken off the drum and changed end for end, thus reducing by the weight of the rope itself the strain upon this point. The writer is not sure that this is quite a safe thing to do, and thinks it much better in such a case to cut off the defective part, and use the shortened rope for a shallower

pit. A winding rope which has been worked upon a larger drum, will, as is generally known, not work so well nor last so long if removed to a smaller drum; but it is perhaps not so well known that in the case of a winding rope being removed from a smaller drum to a larger the same remark applies, but in a lesser degree. It would seem that a rope adapts itself to the conditions under which it works, and resents a change.

The portion of a rope which does not in ordinary winding leave the drum, should occasionally be run off for inspection, and also for oiling, which makes it more soft and pliable. Especially in vertical drums of small diameter, the pressure of the upper coils has an injurious effect upon the lower coils, and in any case it is essential to know the real condition of the whole of the rope. Inspection leads us into danger instead of keeping us out, unless it is thorough.

Forms of Headgear Pulleys.

The question has been often asked—What is the best form of the working part of winding-rope pulleys? About these for round ropes there is no difficulty in deciding off-hand—the pulley must be made to fit the rope. But when we come to deal with flat ropes there is difference of opinion. Some authorities argue in favour of having the working part of a flat rope pulley made convex, that is to say, larger in the central part, so as to keep the rope away from the flanges. They say that flat ropes receive a lot of harm, and their existence as working ropes terminates prematurely, in consequence of the grinding action between the flanges of the pulley and the outside portion of the rope stitching. The writer thinks that flat ropes should work upon absolutely flat horizontal surfaces upon the vertical winding drum and upon the headgear pulley, and his reasons for so thinking are explained in the following sketches, with remarks thereon.

A flat rope may be considered simply a number of round ropes, four or six, held together so as to form one rope by means of stitching. If all the six sections of a flat rope are kept in equal tension, we get good results, if otherwise, the rope fails. Fig. 87 shows a flat rope upon a flat and straight surface, but inclined; section 6

has all the strain, being upon the larger diameter, whereas section 1 has no strain at all. Fig. 88 shows a flat rope working upon a concave surface (exaggerated of course); sections 1 and 6 are on the large diameter, and have all the strain, whereas sections 3 and 4 have none. Fig. 89 shows (also exaggerated) the convex form, adapted in some cases for headgear pulleys. In this case sections 3 and 4, being upon the larger diameter, do all the work and have all the strain, whereas sections 1 and 6, running upon a less diameter, have no strain at all.

In the working of flat ropes we must guard against anything which will cause splitting, and the pulley which answers best for avoiding this is one with a flat and horizontal working surface. The stitching receives more harm from the action of the vertical drum arms than from the pulley flanges. These flanges have no sharp edges, and are continuous, and only a few inches deep, whereas there are six or eight or ten arms to a drum, each about a yard deep, and each knocking against the rope with an edge each revolution; but with proper appliances properly applied a flat winding rope will receive no harm —except regular wear and tear—either from the flanges of the head-gear pulley or the arms of the winding drum. If a rope grinds against the flanges of a pulley, then either the drum or the pulley or both are wrong, and the proper way to effect a remedy is not to make the pulley "convex," but to correct the positions of the pulley and the drum.

Vertical arms of wood for drums are at best not a good contrivance. A better plan would be to have a cast iron drum, split round the circumference, and split across the diameter also. These segments could be neatly turned, firmly bolted together, and the rope would have a true circle to coil upon, no edges to knock against, and the sides would not press out. (See Appendix, Note H_2.)

Taper Ropes.

To some extent taper ropes, both round and flat, are used, the idea of course being simple enough—to produce a rope of uniform strength—to have it less strong and less in diameter at the cage end, where the load is least, and to have it greater in strength and in diameter at the drum

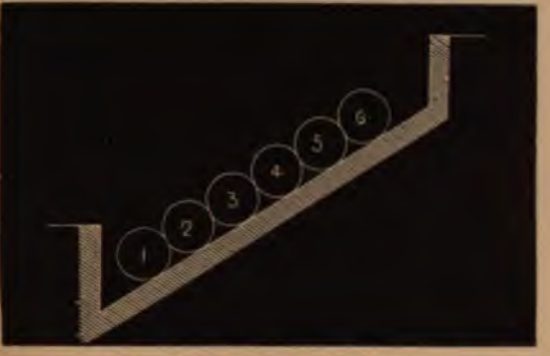

FIG. 87.—FLAT ROPE PULLEY INCLINED.

FIG. 88.—FLAT ROPE PULLEY MADE CONCAVE.

FIG. 89.—FLAT ROPE PULLEY MADE CONVEX.

[*To face page* 68]

FIG. 90.—RECORD BOARD IN ENGINEHOUSE.

The Lancashire Coal Co:

QUEEN VICTORIA PIT.

DEPTH 620 YARDS.

Right-hand Rope:

PUT ON NEW .... 25 JAN., 188—.

CAPPED .... 29 MAY, 188—.

LAST ROPE WORKED .... 2 YRS. 3 MTHS.

And made 125,000 windings.

Left-hand Rope:

PUT ON NEW .... 9 FEB., 188—.

CAPPED .... 9 FEB., 188—.

LAST ROPE WORKED .... 2 YRS. 9 MTHS.

And made 151,000 windings.

H. STANLEY,

Manager.

[*To face page* 69.]

end, where the load is greatest. The theory is perfectly correct, and some weight of rope is in this manner saved; but in practice there is not much advantage. First, the taper rope costs more per cwt., so that, although we get a lighter rope, we pay more for it. Second, the taper rope, from the circumstances of the case, cannot be so well manufactured. Third, there is a little difficulty in the application. Suppose we have a round rope taper, working upon a spiral drum, we shall have the thick portion of the rope coiling upon the small diameter, and the thin portion of the rope coiling upon the large diameter. Suppose we have a flat rope taper working upon a vertical drum it upsets the main principle already laid down at considerable length, namely, the prevention of too much clearance between the arms. We are compelled to provide clearance for the rope in its widest portion, and we must at least maintain this width to the top of the vertical arms, and if there is much taper in the rope there will be far too much clearance for good work where the rope is narrow, and if there is scarcely any taper in the rope, why have any taper at all? The writer sees no reason to swerve from his long-established conviction that the best of all ropes for colliery purposes is one made of steel, and made round and parallel.

Rope Records.

Careful records should be kept in the office and in the winding engine house, showing the comparative lives of ropes. A good practice is to place in each engine house a neat board, something after the form of that shown in fig. 90.

But in the office we ought to have more elaborate information with regard to all ropes used since the pit was fairly got to work. We ought to have the date when put on, the date when taken off, the maker's name, the cost and size and form of rope, and whether made of iron or of steel. To make such a record more complete, we ought to have the depth of the pit, the maximum load, and approximately the number of windings. Unless we have the whole of this information, or a substantial portion of it, we cannot tell which are the best, and which are the cheapest ropes. It ought not to be difficult to arrive at

all this information, and especially the more important—namely, the number of windings. We have attached to all our ventilating and some of our pumping arrangements counting machines, which mark each revolution made in a week, or a month, or a year. We simply need a modification of this to record the number of windings. (See Appendix, Note H_3.)

Comparative Cost of Ropes.

We cannot speak of one rope as being less expensive than another merely because the actual money passed over the counter at the time of purchase was less. Suppose one rope costs £150, and wears two years, and makes 100,000 windings per year. Another rope costs £120, and wears one year, and makes 90,000 windings. The first mentioned rope caused an expenditure of 25 per cent. more in purchasing, but it performed more than 100 per cent. more work than the cheaper one. Mining engineers and colliery proprietors in most things display commendable determination that cheapness shall not be a first consideration, but in ropes too much so-called economy is practised. The result is constant risk and frequent occurrence of accident, and a greatly increased expenditure.

At the Haydock Collieries the rule is to have springs at the attachment of the winding rope to the cage, not unlike the ordinary springs used in wagons and carriages. The strain upon a winding rope is less when the speed is decreasing, greater when the speed is increasing, and greatest of all at the moment of starting. It is to break the suddenness of this shock that springs are applied, and the results have been so satisfactory that with a considerable daily output from a good depth winding ropes have worked for seven years.

Rules as to Strength of Iron and Steel Flat and Round Wire Ropes.

The following may be regarded as giving a simple method of ascertaining approximately the safe working strength of ropes. They are not the result of actual test, so far as the writer is concerned, nor are they absolutely correct. Indeed, no rules of this kind can claim absolute

accuracy, because two ropes of the same size and same material made in the same way will vary in strength. The rules, however, are sufficiently near to be taken as practically correct, and will be easily remembered.

Flat Ropes.

Multiply the width in inches by the thickness in inches, and multiply by 35 for charcoal iron, 55 for crucible steel, and 70 for plough steel. The results are safe working load in hundredweights.

Round Ropes.

Square the circumference in inches and multiply by 4 for charcoal iron, 6 for crucible steel, and 10 for plough steel. The results are safe working load in hundred-weights.

Generally, the breaking strain may be taken at 10 times the safe working load.

Calculations according to the above rules have been made, and the results correspond very nearly with the tables of strengths as published by the rope makers :—

Size and Weight in Pounds per Yard, and Safe Working Load in Hundredweights of Flat Ropes.

Best Improved Steel.

Dimensions in inches.	Pounds per Yard.	Working load in cwts.
$2\frac{1}{4} \times \frac{1}{2}$	5	80
$2\frac{1}{2} \times \frac{1}{2}$	6	100
$2\frac{3}{4} \times \frac{5}{8}$	7	124
$3 \times \frac{5}{8}$	8	144
$3\frac{1}{2} \times \frac{5}{8}$	10	180

Best Crucible Steel.

Dimensions in inches.	Pounds per Yard.	Working load in cwts.
$2\frac{1}{4} \times \frac{1}{2}$	5	64
$2\frac{1}{2} \times \frac{1}{2}$	6	72
$2\frac{3}{4} \times \frac{5}{8}$	7	80
$3 \times \frac{5}{8}$	8	100
$3\frac{1}{4} \times \frac{5}{8}$	9	124
$3\frac{1}{2} \times \frac{5}{8}$	10	136
$3\frac{3}{4} \times \frac{11}{16}$	11	144
$4\frac{1}{2} \times \frac{3}{4}$	$15\frac{1}{2}$	180

Best Charcoal Iron.

Dimensions in inches.	Pounds per Yard.	Working load in cwts.
$2\frac{1}{4} \times \frac{1}{2}$	5	40
$2\frac{1}{2} \times \frac{1}{2}$	6	48
$2\frac{3}{4} \times \frac{5}{8}$	7	56
$3 \times \frac{5}{8}$	8	64
$3\frac{1}{4} \times \frac{5}{8}$	9	72
$3\frac{1}{2} \times \frac{5}{8}$	10	80
$3\frac{3}{4} \times \frac{11}{16}$	11	88
$4 \times \frac{11}{16}$	$12\frac{1}{2}$	100
$4\frac{1}{4} \times \frac{3}{4}$	14	112
$4\frac{1}{2} \times \frac{3}{4}$	$15\frac{1}{2}$	124
$4\frac{5}{8} \times \frac{3}{4}$	17	136
$4\frac{7}{8} \times \frac{7}{8}$	18	144

Round Ropes.

Best Charcoal Iron. | *Best Charcoal Iron (contd.)*

Inches in Circumference.	Pounds per Yard.	Working Load in cwts.	Inches in Circumference.	Pounds per Yard.	Working Load in cwts.
1	½	4	3⅜	4½	36
1½	¾	6	3½	5	40
1⅝	1	8	3⅝	5½	44
1¾	1¼	10	3¾	6	48
1⅞	1½	12	3⅞	6½	52
2	1¾	14	4	7	56
2⅛	2	16	4¼	7½	60
2¼	2¼	18	4⅜	8	64
2⅜	2½	20	4½	9	72
2½	2¾	22	4⅝	9½	76
2⅝	3	24	4¾	10	80
2¾	3¼	26	5	11	88
2⅞	3½	28	5¼	11¾	94
3	3¾	30	5½	12½	100
3⅛	4	32	6	15	120
3¼	4¼	34	6¼	16½	132

Round Ropes.

Best Crucible Steel. | *Best Crucible Steel (contd.)*

Inches in Circumference.	Pounds per Yard.	Working Load in cwts.	Inches in Circumference.	Pounds per Yard.	Working Load in cwts.
1	½	6	3⅛	4	56
1¼	⅝	8	3⅜	4½	60
1½	¾	10	3½	5	64
1⅝	1	12	3⅝	5½	72
1¾	1¼	16	3¾	6	76
1⅞	1½	20	3⅞	6½	80
2	1¾	22	4	7	94
2⅛	2	26	4¼	7½	100
2¼	2¼	30	4½	9	120
2⅜	2½	32	4¾	10	132
2½	2¾	36	5	11	154
2⅝	3	40	5½	12½	175
2¾	3¼	44	5¾	13½	189
2⅞	3½	48	6	15	210
3	3¾	52			

ROUND ROPES.

Best Improved Steel. Inches in Circumference.	Pounds per Yard.	Working Load in cwts.	*Best Improved Steel (contd.)* Inches in Circumference.	Pounds per Yard.	Working Load in cwts.
1	½	10	3	3¾	72
1¼	¾	12	3⅛	4	76
1⅜	1	16	3¼	4¼	80
1½	1¼	22	3⅜	4½	88
1⅝	1½	26	3½	5½	94
2	1¾	32	3¾	6	100
2⅛	2	36	3⅞	6½	120
2¼	2¼	44	4	7	132
2⅜	2½	48	4¼	8	154
2½	2¾	52	4½	9	175
2⅝	3	56	5	11	189
2¾	3¼	64			

N.B.—All the foregoing weights are given for ropes with hemp cores. Ropes with iron cores will weigh one-eighth heavier; but a well made rope with iron core will have its strength increased proportionately. In flat ropes, whether steel or iron, parallel or taper, at least one-eighth of the entire weight represents the stitching, which, although essential to the working of the rope, adds nothing to the strength of it. Whereas in a round rope we have no stitching, and consequently none of this useless encumbrance of weight to deal with.

CHAPTER IX.

CONDUCTORS AND CAGES.

Necessity for Conductors—Various Kinds—Rigid and Flexible—Iron, Wood, and Wire—Where Rigid Conductors are Essential—Where Flexible Conductors can be applied—Disadvantages of Iron and Wood Conductors—Advantages of Wire Conductors—How to Secure Wire Conductors in the Head Gear—How to Secure them below—Defects of Screw Arrangement—The Dead Weight and its Advantages—Single Weights or a number of Disc Weights—Clearance below Weights—Attachment between Conductors and Weights—Appliances at Collieries of Wigan Coal and Iron Company—Inspection of Wire Conductors—Mishaps with Conductors—Arrangements of Conductors—Two, Three, or Four to each Cage—Two Cages in One Shaft—Danger of Collision—Safety Conductors, how placed—Putting Wire Conductors in—Weight on each Conductor—Cages and Chains—Number of Chains—Adjusting Screw—Examining and Annealing—Object, and how performed—Strength of Pins and Shackles and Chains—Connection of Chains and Rope and Cage—Catches to keep Tubs in Cage—Foot, Pendulum, and Bow—Accidents through Tub leaving Cage—Best Form of Catch Arrangement—Catches for Cage to rest upon—Worked by Banksman or by Engineman—Experience at Burnley without Catches—Assistance Engineman can give in Unloading and Loading Cages.

NECESSITY FOR CONDUCTORS.

THERE is so intimate a connection between ropes and conductors at collieries that, having in the preceding chapter dealt with ropes, it seems quite a natural progression that the succeeding chapter should be upon conductors. In the primitive mining days colliery operations were carried on in happy ignorance of any and all conducting arrangements. The depth was inconsiderable, the load trifling, and the speed of the slowest. And in no case did more than one rope work in one shaft. But, with increasing depths and loads, and with two ropes working in one shaft, and a speed reaching, at some collieries, one mile a minute, efficient guiding arrangements became absolutely necessary. What we do with these guides is, first, we keep the movement vertical, and keep the cage away from sides of pit; second, we keep the cage from catching any

thing in the pit, third, where two ropes work in the shaft we prevent collision. In the first case there is not much difficulty, because we have a clear pit and only one rope, but in the second the matter is more complicated, by reason of pumps, &c., in the shaft, and the third is the most important, and at the same time difficult of the whole, because if the cages meet when empty or loaded with fuel the ropes and the cages may break, and if they meet with men in, loss of life is almost certain.

Various Kinds of Conductors.

Conductors may be either rigid, of iron or wood, or they may be flexible, of strong wire, something after the manner of wire ropes.

In a shaft where there are pumps, and therefore a good many horsetrees, and not much clearance, rigid conductors are inevitable, and it is simple waste of time to argue against them. But it is only where such is the case that rigid conductors should be used.

Rigid conductors, whether of iron or wood, require a good many horsetrees to make them secure, and this injures the shaft, causes considerable expense at first, and entails almost constant expense afterwards. The vertical line cannot be maintained, and consequently the motion of the cage up and down is not free, and a considerable amount of friction is the result. So much injury has been done to shafts by cutting scores of large holes into which to fit the horsetrees that it is now considered good practice to insert cast iron boxes in the brickwork as the pit is being sunk. The timbers can afterwards be inserted in these cast iron boxes and made secure without cutting into the brickwork. An objection to wood conductors is that they are liable to break, and to iron conductors that they do not provide for expansion and contraction.

Advantages of Wire Conductors.

With wire conductors no horsetrees whatever are required at the commencement, and consequently no repairs afterwards. The conductors are put in in one length from top to bottom, and only need securing at those two points. If contraction from cold or expansion from heat arises, no evil results follow with wire conductors, because they are

free to increase or decrease in length. The vertical line is maintained, and, being flexible, the movement of the cage is free and unfettered, and scarcely any friction is experienced.

How to Secure Wire Conductors.

It was suggested some years ago to secure wire conductors by screwing them under a strong wooden sill in the sump hole, and above a strong beam at the top, in the headgear, so as to get a perfectly rigid conductor throughout. There would be no impossibility in carrying out an arrangement of this character, which dispenses altogether with weights, provided we could rely first upon an absolute temperature at all times, and, secondly, on the conductors themselves not stretching because the moment they stretched, however slightly, the screwing above and below was useless. And as regarding the temperature, we cannot depend upon it being anything like uniform, and any alteration would cause serious results, owing to the great length of the conductors. If the temperature rises, the length of the conductor increases, it becomes quite slack, and may prove a source of danger. If the temperature falls, the length of the conductor decreases, and as there is no provision for contraction, the conductor may break, and has been known to break at an unfortunate time.

What we want is an arrangement which enables us to put on exactly the amount of strain we wish, and which, whilst giving as much rigidity, that is, tightness, as the method just described is unaffected so far as its efficiency is concerned by variations of temperature. Whether expansion or contraction takes place the conductor can adapt itself to either, without becoming slack or running the risk of breakage. This is shown in figs. 91, 92, and 93. Each conductor is made secure at the top of the headgear with wrought iron clamms, as many as may be needed—one pair up to 200 yards deep, two pairs up to 400 yards deep, and so on. These clamms grip the conductors and rest upon timbers of sufficient strength, as shown in fig. 88. Care must be exercised in fitting the clamms nicely to the conductors, or else the clamms, instead of holding the conductors firmly, may actually nip and tend to break them.

Fig. 91.—Clamming Wire Conductors at Top.

Fig. 92.—Conductor passing through Sill.

Fig. 93.—Conductor passing in Face of Sill.

Fig. 94.—Old Arrangement of Attaching Weights.

Fig. 95.—New Method of Attaching Weights.

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At the lower end, in the sump hole, as shown in fig. 94, heavy weights are placed upon clamms, one or two pairs gripping the conductors; the weight varies according to the depth—for shallow pits 20 or 30 cwt. may prove sufficient, but for deep shafts as much as 3 or 4 tons may be placed on each conductor with advantage.

Formerly, and even now in many cases, these conductors pass through strong timber sills, as shown in fig. 92, but there is a twofold disadvantage in this arrangement. (1.) Water and dirt collect round the portion of the conductor within the timber, and corrosion results. (2.) No examination can be made of this portion of the conductor. The improved arrangement, as shown in fig. 93, is not to pass the conductors through the timber sills at all, but to let them pass in front, prevented from having too much freedom of oscillation by small iron fastenings connected to the sills, and through which the conductors pass. It was also universally, and still is very largely, the custom to build up at the bottom of each conductor a series of circular flat weights. The bottom weight rested upon a large pair of clamms, which firmly gripped the conductor, and on the bottom weight was erected a structure consisting of twenty or thirty similar weights, not exceeding 2 cwt. each. The only advantage of such an arrangement is that there is no trouble in sending such small weights underground or in putting them on, and we can adjust to a nicety by adding to or taking from the weight we want upon each conductor. But the disadvantage is that a portion of each conductor cannot be examined, and it is a portion which demands examination, in consequence of water lodging and causing corrosion. This arrangement is sketched in fig. 94, and the improved method (fig. 95), namely, to have only one solid circular weight instead of twenty or thirty disc weights, and instead of having the conductor passing through the weights, to secure it above the weight. In this way we avoid corrosive influences, and we need no examination. And as regards adjusting the exact weight to be placed upon each conductor, we ought to know from experience what weight is sufficient for certain depths. But the more correct plan is to have a wire conductor whose working load is sufficiently high, and then if we

make a mistake at all, letting it be in putting too much rather than too little weight on. A wire conductor is not like a wire rope, it has really nothing to do, and in the correct sense of the term it does no actual work, because to do work weight must be raised. The mere friction of the slide boxes of the ascending and descending cages upon the wire conductors will have no injurious influence, provided the conductors be kept clean and greasy. Sufficient clearance must in all cases be provided in the sump hole below the bottom of the weights. In furnace shafts this is extremely important, because an increase in temperature will lengthen the conductors, and weights have been known in consequence of this to rest upon the bottom, and the conductors having consequently become slack have been dangerous. And even in any shaft, whether furnace or not, water gets into the sump hole, and by rising above the weights will deduct from their gross 2-15ths, and in cases where dirt accumulates it may get under the weights, and surround the weights and make the conductors useless. At the collieries of the Wigan Coal and Iron Company the attachment of conductor weights to conductors is brought to practical perfection. The attachment is above the sills which steady the conductors, and all oscillation and the collection of dirt with injurious results is prevented by making the connecting piece between the conductors and the weights pass through and fit tightly in a square box.

A distance of two yards is little enough for clearance, and, as may be shown in a future chapter, it is easy, with a little consideration, so to arrange the timbers for steadying these conductors and these weights as to be as little in the way as possible, and not prevent a good sized water-tank or hoppit getting right to the bottom of the sump-hole. (See Appendix, Note I_1).

Wire conductors scarcely receive the examinations to which in common with all parts of colliery machinery they are entitled, and accidents have happened which such examinations would have avoided. There was one case where a capstan rope crossed through the head-gear over one pit to pass to another, and in doing so rubbed against a wire conductor. This went on for years, was not observed, and one fine morning "the last straw broke

the camel's back," and the conductor fell down the pit. Accidents happen much more frequently another way, and have caused, in addition to destruction of property and stoppage of work, also loss of life. The wear upon wire conductors from friction, and the bending of the conductors from oscillation of the cage, will do no harm if the conductors are made of good tough iron, because the friction will not perceptibly rub them away, and the oscillation will not break them. But too often the iron of which wire conductors are made is inferior and most unsuitable, because, forsooth, the price is low—as if any price or no price at all could be too low for inferior iron. The friction rubs them away, and the oscillation breaks one wire, the broken ends stand out, and the ascending or descending cage, with its slide boxes, comes in contact with a broken end, and carries the wire before it, unravelling and probably breaking the conductor. We can prevent the first-mentioned kind of accident by making not exactly more frequent but more thorough inspection. Thanks to a beneficent Parliament and a continuous succession of grandmotherly legislation, half the time at collieries is taken up with inspection of one kind and another. What we want with wire conductors is not to be messing and examining them every day, but to give them a thorough overhauling from end to end once in each week. And as to the second kind of accidents, arising from the use of defective material, the remedy is self-evident. So long as no lives are lost, it is a good thing when accidents occur from this cause; they give a lesson for the past, and a warning for the future.

Arrangement of Conductors.

Now the question comes, How many conductors should we use? First, in a shaft worked only with one rope. Of course, not less than two in any case, and if the cage is a large one, made to hold three or four tubs on each deck, three conductors answer better and give a steadier movement to the cage. But the difficulty does not arise in this case, as no trouble need be experienced with only one cage working in a shaft. The circumstances are very different with two ropes and two cages, and in such a

case we must not only provide a free and easy but vertical movement, which is the essential principle of wire conductors, but we must prevent collision between the two cages. Figs. 96, 97, 98, 99, and 100 show several sizes of cages arranged for one, two, three, and four tubs on a deck, and the number and position of conductors suggested in each case is shown by dots and lines passing through the dots. The arrows show how the tubs enter the cages, and the dotted lines are to show the cage chains.

Safety Wire Conductors.

The general practice with two cages in one shaft is to place them as far apart as possible. But unless the shaft is very large, and the cages small, the distance between them cannot be great, and certainly not great enough to prevent their meeting. Experiments have been made with two cages working in the same shaft, and it has been proved practically that in a pit 300 or 400 or more yards deep, cages, even two feet apart, can with almost the action of the current of air only be brought into collision. The slight irregularities in winding, and the tendency which all ropes have to twist, cause oscillation more than sufficient to cause cages to meet. The writer's contention is that it is scarcely possible to have the cages so far removed as to make their meeting impossible, and that is the point, because what advantage and what safety can there be in cages passing without meeting a thousand times, if there always remains the risk of collision during some one unfortunate winding? We must therefore proceed upon other lines, and ensure safety by making a meeting practically impossible. It is a mistake to have cages too far apart. They should be brought almost close together, and extra conductors should be placed between the two cages to prevent their meeting. Figs. 101, 102 and 103 show several cage arrangements as in actual operation with conductors to each cage, and in addition two conductors in between. The dotted lines show the cage chains, the dots with lines running through show the conductors and the arrows show how the tubs enter the cages. The writer, has, with some success, adopted this plan at several collieries 400 and 500 yards deep, and

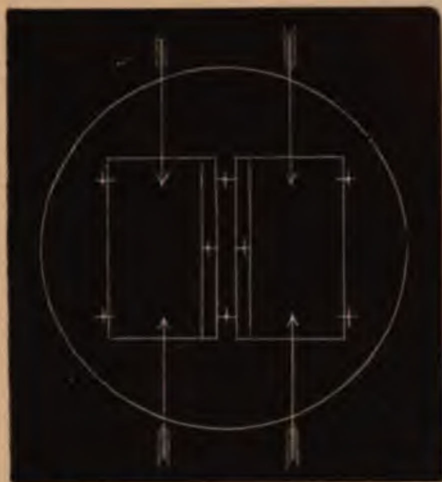


Fig. 102.—Two Cages, with each two Tubs and three Conductors.

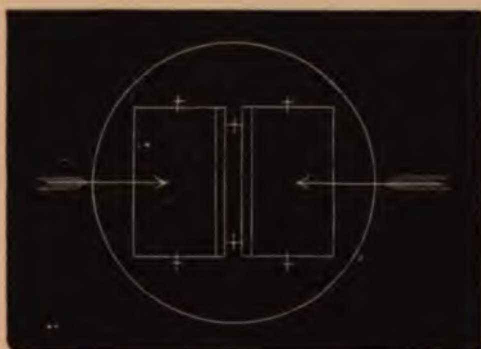


Fig. 103.—Two Cages with each two Tubs and two Conductors.

[*To face page* 80.]

Fig. 96.-
Tubs,
Condu

Fig. 98.—
Tubs,
Cond

recently at a new colliery more than 600 yards in depth, and would have no hesitation in applying it to any pit, however shallow or however deep. In some cases there are only two conductors to each cage, in others three, and in some as many as four, and the results are in favour of three conductors to each cage, as against either two or four. The triangular arrangements give the steadiest movements. But in all cases there are two conductors between the cages so fixed as to prevent oscillation causing collision, and also to prevent an end of a cage getting round by reason of end oscillation. The cages themselves are from 12 to 18 in. apart, back to back, and along the top of the back of each cage is attached a rubbing piece of timber, a few inches deep. Fig. 104 shows an elevation of a middle or safety conductor, and its position relatively to the two rubbing pieces. These pieces are so arranged as to be within 2 or 3 in. of the middle conductors. These rubbers were found to wear away too rapidly, and latterly strips of brass have been fitted into the timbers, and with excellent results. The advantage of this arrangement is that not much clearance is required, and the two cages being brought so much nearer together, pit shafts which would otherwise be considered too small, will admit and allow to work quite safely two cages. The writer in this is not expressing any mere theoretical opinion, but is giving the result of long practical experience with these appliances. What gave rise to its introduction was the arrangement being required for working two cages in a shaft 500 yards in depth, and so small in diameter that even when the two cages had been brought within a few inches of each other there was but very little clearance between the corners of each cage and the brickwork of the shaft. This arrangement was applied more than twelve years ago, and has continued at work ever since, and is working now. Whatever the diameter of the shaft, whether large or small, whatever the depth of the pit, whether deep or shallow, and whatever the size of the cages, there should be three wire conductors to each cage, two safety wire conductors in between the cages, and the top of the back of each cage should be lined up with rubbing pieces of timber, so as to be brought within a couple of inches, or thereabouts, of the

middle conductors. Such an arrangement effectively made will prevent cages coming into collision.

Cages.

It will be observed that with such arrangements as the foregoing, the catches supporting the cages when decking at the surface or at the pit bottom, cannot, as is usually the practice, be applied at the sides, and must give their support at the end of the cages. With a cage of ordinary length, adapted for two tubs on a deck, and having a length from 7 to 8 ft. there is no difficulty. But when a cage has to carry 6 tubs, end to end, and has a length of 11 ft. or more, something special must be arranged. Fig. 105 shows such a cage in elevation. A span of 11 ft. from catch to catch is a good deal, and such a cage should have its angle-iron of each deck of more than usual dimension, and the upright bars should also be made proportionately strong, the thickness being the same in all the uprights, but the breadth should be greater for the middle uprights, and less for those near the ends of the cage. Cage-bottoms on which the tubs rest are commonly made of wood battens; but in case the cage has to work in a furnace shaft, timber does not answer so well, and consequently iron bottoms are used. (See Appendix, Note I_2.)

Cage Chains.

Generally cages are suspended by four chains, but for large and heavy cages six chains are better; but when six chains are attached it is not an uncommon thing to see the corner chains used for regular work and the two middle chains arranged so as to come into action if the others give way. The most effective arrangement would seem to be, whether four chains or six are used, to have them all in actual work and made so that they all can work together. It is difficult to get chains made of fixed links only of a uniform length, and to make them uniform when attached to the cage a twist is administered to the longer chains. But this is a very imperfect method, because, first, a twist may be either too much or too little and because, second, this twisting of the chains gives a twisting inclination to the cage, and moreover, causes it to hang unevenly.

FIG. 104.—SAFETY CONDUCTORS AND RUBBING PIECES.

FIG. 105.—ELEVATION OF TWO-DECK CAGE.

FIG. 106.—ADJUSTING SCREW FOR CAGE CHAINS.

[To face page 82.]

Adjusting Screw.

Fig. 106 shows an adjusting screw which can form part of each cage chain, and enables us to get over the whole difficulty. With this it is easy to lengthen or shorten any chain, so that the manufacturing the chains at first of exact uniform length is not at all material. We can at will lengthen one and shorten another, and by bringing them all to one exact length, we cause them all to have an equal amount of strain, and the cage will hang quite evenly and quite steadily without any tendency to twist. And when the machinery inspector makes his daily examinations he can examine these chains, and tighten or slacken each as need be.

Examining and Annealing.

Cage chains throughout should have careful examination, because there have been cases where links have in reality been dangerously weak, and yet to all mere superficial inspection, were in good order. In course of time the links wear into each other, and to such an extent as to lose half their thickness. A mere general inspection is of no avail in laying bare such defects. Accidents may happen also from wrought iron links losing their fibrous characteristics and becoming crystalline, like cast iron. This is attributable to the shocks experienced in starting each winding and in decking. Annealing the chains about every three months is a perfect remedy, and is accomplished by slowly heating the chains up to a dull red temperature, and then allowing them to cool down in the atmosphere.

Strength of Pins and Shackles and Chains.

It is of some service to be able to calculate easily the strength of chains, &c., as in ordinary use for winding. Taking really good iron, possessing an ultimate tenacity of from 20 to 25 tons per square inch—and certainly no iron should be used in winding operations that does not possess this tenacity—we work out a rough and sufficiently correct practical rule after the following fashion:—Square the diameter in eighths of an inch and mark off the last figure as a decimal, and this gives us the safe

working load in tons. For example, a link of 1-inch iron treated in this way, $8 \times 8 = 6{\cdot}4$, showing a safe working load of $6\frac{1}{2}$ tons. Taking a link of $\frac{5}{8}$-in. diameter, $5 \times 5 = 2{\cdot}5$, showing working load $2\frac{1}{2}$ tons.

The firmest connection of cage chains to cages or cage chains to rope cappings is to have the pins screwed into the shackles, this giving much more security than split pins or cotters.

Putting wire conductors in position is a work requiring considerable care, and some skill, especially when there are so many in one shaft. One is liable to get twisted round some of the others, and cause much trouble in getting right. In some cases the conductors are taken coiled up as received from the makers to the pit bottom and drawn up. The other and better method is to coil them upon the winding or capstan drum at the surface, and lower them off steadily, one at a time, of course, with a weight at the end. As each reaches the bottom it is fastened against the pit side until all the conductors are in, when they are placed correctly in position.

Accidents occur in shafts through tubs either not being put properly into the cages, or getting wrong in course of winding. The time at good collieries occupied in taking tubs out and putting tubs in is so short, amounting to only a few seconds, that there is little wonder the tubs get wrong sometimes and falling out of the cage whilst ascending or descending break themselves and something else. A serious mishap, which might have been very much worse, occurred a good many years ago, before mines' regulations were so strict. There were two cages in the shaft, and one was a through cage, because the hooking on was on one side and the banking on the other. Ten men had got into the cage at the bottom, and had been drawn up a few feet to allow some empty tubs to be put in the upper deck of the cage at the top. The catches were wrong, and a tub was pushed through the cage, instead of stopping in it, and fell down the pit. The winding engineman saw the occurrence, and with excellent presence of mind, such as really good enginemen can show, lowered the cage containing the men the few feet that he had raised it. The men heard the falling tub, and all escaped but one. Ten men might have been

killed—one was badly injured. (See Appendix Note I_8,) There are various kinds of catches in the cage, foot catches against which the tub axles run—the defect is that the axles are strained; pendulum catches swinging from above the tubs—and if the tubs are of wood these pendulums break the ends; bow catches which extend all along or all across the cage, and which are liable to rise. Perhaps the best arrangement of cage catches is to combine the bow and the foot catch, but whichever kind we adopt it is essential that they should be in good order, and throw as little work as possible upon the banksman. The other catches are those upon which the cage rests. These are in some places getting out of favour, it being found better to dispense with them—time is saved, and winding ropes receive less injury. In other cases where used the banksman has nothing to do with these catches; they are worked by the winding engineman. It does seem desirable either to do without them, or arrange them to be worked by the engineman, because the divided responsibility between the banksman and engineman sometimes causes accident.

CHAPTER X.

COLLIERY HEADGEARS.

Material for Construction—Iron or Wood—Advantages but Expensiveness of Iron—Cheapness of Wood—Some Attention due to Appearances—Form of Headgear for two Pulleys and two Ropes—Width of Headgear—Height of Headgear—Defective Forms of Headgear—Lines of Main Posts and Back Stays—Principal Strains Compressive—Various Arrangements of Pulleys—Angle of Rope—Under and Over Rope—More Wear on Under Rope—How to have both Over Ropes—Adjustable Pedestals for Headgear Pulleys—Need of Adjustment—Foundation of Headgear—Blast Furnace Slag—Its general Uses—Charles Wood, of Middlesbro'—Feet of Main Posts—Advantage of keeping above Ground—Renewal of Bottom of Main Posts—Feet of Backstays—How supported—Provision for Detaching Hooks—Transverse Timbers for supporting Conductors and Weights—Strength of Timbers—How calculated—Extra Allowance for Shock in case of Detachment—Margin of Safety—Built up Beams—Detaching Hooks, Safety Catches, and kindred Appliances—Defects of all Arrangements for Overwinding—Proposed Automatic Gear to shut off Steam and apply Brake—Defects of such Appliances—Requirements of effective Arrangements—Suggestions—Fencing round Top of Headgear—Accidents whilst oiling Pulleys—Advantage of Lubricators—Strength of Axles—Friction of Axles—Fitting Pulleys upon Axles—Need of keeping Bearings level—Supporting centre of long Back Stays.

We shall deal in this chapter with headgears of timber, because, except at the very largest collieries, timber is likely to be as much the rule in the future as in the past. Timber is very much cheaper, and will do well enough for a term of thirty years, which is not a bad average life for a colliery. Iron makes a firmer structure, and avoids danger from fire, which is undoubtedly an important consideration, but, as probably in some other portion of this work iron erections will be dealt with specially, we confine ourselves at present to headgears of wood. There is one remark that may be made, and which applies equally to both kinds, and that is that a little more attention might very well be paid to appearance.

Colliery erections, and the smoke issuing in great volumes from the chimneys, and the vast mounds of dirt and heaps of coal that accumulate in their vicinity, do

not, under the most favourable circumstances, add to the beauty of the landscape; but really, with some collieries, it does look as if a consistent endeavour were being made to have the whole thing made as unprepossessing as possible. When a colliery is working it is not more difficult or expensive to keep it neat or tidy than to manage amidst roughness, dirtiness, and untidiness. And in building an engine-house, a chimney or a headgear, the same money badly spent in erecting unpleasing structures would be found sufficient, if more care and judgment were exercised, to make the whole thing pleasing to the eye. And suppose it adds slightly to the expense, we have as much claim upon colliery proprietors to do a little for the sake of mere appearances, as we have upon railway companies and other public bodies to do a good deal.

We take as a good type of well-made, neat-looking, and inexpensive headgear, one designed for two ropes, and with the two pulleys side by side and level with each other, as shown in fig. 107 and 108.

The distance between the winding ropes, that is, the centres of the cages working in the shaft, determines the width of the headgear at the top. The distance from post to post at the bottom is determined by the necessity to give the feet a firm foundation clear of the pit shaft. The width of the back stays at the lower end should be such as to give the same batter outwards that the main posts have. The height of the headgear is fixed by the amount of clearance required for the convenient working and decking of the cage. It is found that with an ordinary double deck cage, a height of about 40 ft. from level of pit-bank to centre of pulley answers well. With a one deck cage less would suffice, and with a three deck cage more might be needed. Rather more height is required now than formerly in all cases since the general application of safety hooks, and in many cases recently, headgear pulleys have had to be permanently raised 2 or 3 ft. to give the needful height for the insertion of overwinding appliances. Too much height of headgear is to be deprecated; it answers no useful purpose, and whilst making the structure much more unstable, adds materially to the cost. Great height does not make accidents less likely, because any

height we can possibly add to headgear is so small a proportion of the distance a rope travels in one revolution that it is not worth consideration. And as an actual fact where there is little clearance accidents are not more frequent than where there is considerable. The distance between the main post and the front post depends on the diameter of the pulley, that is, the distance from centre of one post to the centre of the other equals the diameter of the pulley.

Sometimes considerable quantities of water have to be wound from the sump, and as good a plan as any is to hang a tank below the cage with a clack in the bottom to allow the water to enter, and a clack in the side to allow the water to be discharged. In such cases it may be found desirable to make the headgear somewhat higher.

Sometimes headgears are erected as in figs. 109 and 110, both of which are clearly wrong, because the strain acts transversely, and obtains the least resistance from the timber, whereas wherever possible we should make the pull of the rope exert compressive strain upon the main parts of the headgear. The chief principle of construction for headgear posts and backstays is that they should be parallel with lines of the rope passing to the drum, and passing down the pit, as shown in fig. 107.

Sometimes, for various reasons, but chiefly to make the angle of the rope equal in both cases, one pulley is put in advance of, or below, another, as shown in figs. 111 and 112, but this arrangement is neither necessary nor desirable, nor does it answer any good purpose. The "under" rope will give results inferior to the results of the "over" rope, not so much because the angle is different, or because it coils further round the pulley, but because whereas the "over" rope bends all one way, the same in passing round the headgear pulley as in passing round the drum, the "under" rope bends two ways, one going over the pulley and the other going round the drum. Of course, with two ropes on the same side of the engine-house this is inevitable. But with large and well-made and well-fixed pulleys, and large and well-made and well-fixed drums, and the ropes carefully put on and carefully used, the evil working of an "under" rope can be brought to a minimum. A useful appliance is shown in fig. 113. It

is in connection with headgear pulleys, and the pedestal plates on which they rest are so arranged with screws that a pulley can, when occasion requires, be adjusted in any direction.

This is a useful appliance, because as a rope wears into the rim of a pulley the pulley wants moving forward to keep the line of rope correct in the pit. And at times, owing to defective foundations, headgears settle a little either one way or another, and this necessitates some adjustment of the pulley.

As to the stability of the headgear, everything depends on the foundation of the main posts. The groundwork should be got out to a firm bottom, brickwork firmly set upon this, and a good ashlar stone on the top, not less than 2 ft. thick and a yard square, for each post to rest upon. (See figs. 114 and 115.)

The difficulty is overcome before it begins if we can excavate down to a solid bottom, but when no such firm foundation can be obtained and the deeper the excavation the more treacherous its character, then we have a troublesome task to gain a good footing for the headgear posts. In such a case blast furnace slag exactly fulfils all requirements. It simply needs a good area, and layers of round or rough slag put in and the slag dust well washed in to fill up all the crevices. It will set into one mass of rock, and if it needs removal at any time, will require blasting. It seems something more than a pity that in many of the iron districts so much of this blast furnace slag, which is useful for mortar making, and for foundations and walls and streets and railways, should answer no other actual purpose than constructing spoil banks. It is surely not too much to hope that ere many years have passed away this great waste product from our ironworks may take its position as a really useful commodity.

There is no intention to ignore the laudable efforts of Mr. Charles Wood, in the Middlesbro' district, to apply slag usefully, but all that has been attempted and accomplished utilises but a small percentage of the quantity made throughout the country.

The feet of the headgear posts should fit into cast-iron shoes, and these shoes should rest upon the stones just referred to, and should be above the level of the ground,

as shown in fig. 115. The writer had some experience with a large and heavy headgear for a pit of considerable depth, and the feet of this headgear were a little below the level of the ground. The damp struck up, and about 2 ft. of the lower end rotted away, nearly bringing the edifice to the ground. These rotted ends had to be sawn away, and new timbers spliced to the old posts. Then an equally important matter is securing the lower ends of the backstays. Sometimes the bottom ends are on a level with the feet of the headgear posts, but this is not a good arrangement, and does not tend to stability. A better plan is when the winding engine house floor is level with the stage, and consequently some 20 ft. higher than the feet of headgear posts. The backstays are brought down a little below the engine-house floor and secured to the engine-house wall. At other times they pass through the engine-house wall and are secured to the engine pillars. Perhaps as good an arrangement as any is to allow the backstays to press against the engine pillars horizontally, and also rest upon a specially built-up pillar which takes the vertical pressure, and is shown in fig. 116.

In connection with headgears we have now not only to provide for the conductors already referred to in the last article, but provision must often be made for the detaching hook gearing. And whereas the strain brought to bear upon the headgear parts and backstays is compressive, and not likely to even approach doing injury, because the headgear is always stronger to resist that strain than any force that can be brought to bear upon it, the strain upon the timbers supporting the conductors is transverse, and much more likely to do injury. We have not only the weight of the conductors themselves, and the weights hanging on to each, but we must be provided against the shock which will result if an overwind is made, and the cage with its load, after detaching, falls back two yards upon the detaching plate. A safe rule—and in all colliery calculations safety holds first place—would be to assume the total weight of conductors as acting at the centre of the supporting pieces, and have the timbers of such number and dimensions as will make not only their breaking strength exceed the load, but will allow their safe working strength, which is only one-

Fig. 116.—Foot of Head Gear Back Stay.

Fig. 117.—General View Top of Head Gear.

[To face page 92.]

tenth of the breaking strain, to considerably exceed the total load.

With headgear pulleys 14 ft. diameter, we may assume the span of these supporting timbers as 13 ft. The total weight may be taken at 32 tons, being 4 tons for each of eight conductors. If we assume four supporting timbers, that means exactly 8 tons, or 160 cwt., on each timber. Elaborate experiments have proved that good average oak or pitch pine 1 in. square, and resting upon two supports 12 in. apart, break with 5 cwt. placed in the middle, which means a safe working load of one-tenth = ½ cwt. Experiments have also proved that as the breadth increases, and as the square of the depth increases, so does the strength; but just as the length between the supports increases, the strength decreases. The figures for our calculation are, on the one hand, the load is 160 cwt., and this must not exceed the safe working load of a piece of timber whose span we know to be 13 ft., and whose dimensions we will take as being 18 in. deep and 14 in. broad; ½ × 14 in., the breadth = 7 cwt. × 18 in., the depth = 126 cwt. × 18 again for square of depth = 2,268 cwt. ÷ 13 ft. span = 174 cwt. Thus we show that the timbers proposed to be used would have a safe working strain in excess of the working load, 160 cwt. It is quite clear that we have given ourselves a considerable margin, because we calculated that all the weight would act at the centre of the timbers, whereas, according to the arrangement illustrated in our chapter on conductors and cages, only two of the eight conductors will act at the centre, and the remaining six conductors will be 4 ft. from the centre, which will materially lessen the maximum load. On the other hand, we have made no allowance for the shock of a returning cage after an overwind, which would administer a serious blow to the whole fabric of the headgear.

Should any difficulty be experienced in obtaining sound timber so large as we have named—and of course even greater dimensions may be needed—then we must have recourse to a built-up beam, which we can make as large and as strong as we please. For example, we could hardly obtain one piece of timber 30 in. deep and 24 in. broad, but we could readily enough get four pieces each 15 in. deep and 12 in. broad.

Fig. 117 shows a general arrangement of timbers for supporting the wire conductors, and also in connection with a detaching hook.

This stage of our subject may be considered an opportune time for touching upon some appliances recently introduced for the absolute prevention of overwinding.

The various detaching hooks and kindred appliances now attached to winding ropes do not prevent overwinding exactly, but they separate the rope from the cage, and whilst the rope passes freely away, the cage falls back and is supported upon the timbers to which we have just made reference. But the more recent appliance, as the writer understands it, causes no detachment; it shuts the steam off the engine and applies a brake. Such an appliance is effective so far as an engineman starting the wrong way is concerned, and this is an accident of somewhat frequent occurrence, but does not do much harm, because the speed has scarcely attained to anything, and the engineman soon discovers his mistake. The appliance can hardly be recommended simply for the correction of mistakes made by enginemen starting their engines the wrong way; and in the event of the engine going the right way, and the engineman losing control, it can hardly be effective if it only operates after the cage has reached the pit bank, because beyond that point a few feet of distance does all the mischief.

A testimonial has been published which is very satisfactory and creditable as far as it goes. It states that with a speed of 15 ft. per second, which means 10 miles an hour, this appliance did its work. This statement is in all probability absolutely correct, although no information is given as to how the actual speed at the moment was arrived at. But will the appliance act at 90 ft. per second, which means 60 miles an hour? No brake power that could be applied would stop an engine in the short distance of clearance above the pit bank, not amounting to one-fourth of a revolution of the drum; and if such a brake could be applied it would accomplish what was not desired—it would smash the engines. On the other hand, it would not accomplish what is desired—it would not stop the cage; and it is quite useless stopping the engines if the cage continues to ascend. A cage travelling at such

a velocity as 90 ft. per second will rise by reason of the momentum it has stored up, to a height much greater than the height of the headgear, however powerful the brake-power applied to the engine, unless similar brake-power is applied to the cage itself. It will never do to bring the engines to a stand instantaneously, and to allow the ascending cage to continue in its path of destruction until it has expended the power stored up in it.

The writer has long entertained the conviction that a thoroughly effective apparatus to prevent overwinding must combine, first, a powerful brake to stop the engines; second, a good detaching hook to liberate the rope; third, an appliance to check the movement of the cage in a more efficient manner than allowing it to dash with destructive force against the timbers of the headgear. The two somewhat crude ideas which have suggested themselves to the writer, and which now, in their rough, unhewn condition are herewith placed freely at the disposal of a more inventive and finishing intellect, are first, to arrange the receiving rods which guide the cage into the headgear in such a manner that the cage ascending above a certain point will gradually wedge itself tighter and tighter. This seems an inconvenient sort of arrangement, because it is rather too obvious that the cage would have a tendency to wedge itself in ordinary working. Second, to surround the wire conductors with spiral springs, which the ascending cage, on passing above a certain point, would spend its accumulated energy upon gradually instead of suddenly, as at present.

So much new light has been thrown on the whole subject of detaching hooks, safety cages, and kindred appliances since the lecture on winding and overwinding was delivered and published in 1880, that the writer has been urged to republish the old lecture with the new information resulting from experience added. The better course will be to devote a special chapter to the subject. Meanwhile, it was thought that in discussing the general principles of headgears the time and the circumstances were alike favourable for just touching upon this well-worn but ever-fresh and interesting, and not even yet fully developed subject. (See Appendix, Note J.)

Headgears, whether of wood or iron, should be con-

structed so that a moderately active banksman can make his way to the pulleys for the purpose of oiling, and should be so fenced on the top that a strong gust of wind will not blow the banksman off the headgear. Without having any sympathy at all with the excessive fencing now insisted upon at collieries, and which, carried to excess, becomes a source of danger rather than a cause of safety, we can all agree that such exposed positions as a banksman occupies upon a headgear ought to have some p:otection. Several years ago one poor fellow was engaged oiling his pulleys, and either he slipped, or the wind blew him, or the engine started and the pulley knocked him off—it was never known exactly which—but whatever caused the accident, he fell down the shaft, some 400 yards deep, and was dashed to pieces.

But such arrangements might very easily be made as would reduce the number of times a banksman had to ascend a headgear to a minimum, and that is the effective method of lessening danger. All headgear pulley journals should have lubricators attached, which, once charged, would go on oiling the pulley for a fortnight, and instead of doing it merely in gushes, like the banksman with his oil-can, would do it continuously, and, of course, much more efficiently, with considerably less oil.

Care ought to be exercised also in constructing head-gears to proportion the pulley bearings correctly. The pulley axle should be so strong as to make accident impossible, but we ought to have strength, and also such an axle as will give the least possible amount of frictional resistance.

We must bear in mind that all the load rests upon the bearings of the axle, and that the friction of bearings increases with the load and also with the distance travelled. We cannot help the load, but we can reduce the distance which the bearings travel, or rather are travelled upon, in two ways, namely, first, by keeping the pulley as large as possible, and, second, by keeping the journals as small as possible. This can be made clear by a simple illustration. Suppose a headgear pulley, 7 ft. diameter, and a journal, 8 in. diameter, for a pit 300 yards deep. The pulley will revolve forty-one times each winding, and the distance travelled by the journal upon its bearing will be 85 ft. each winding.

Suppose, for the same pit, a pulley, 14 ft. diameter, and a journal, 4 in. diameter. In this case the number of revolutions will be twenty and a-half, and the distance travelled by the journal upon its bearings 21¼ ft., being only one-fourth of the amount in the previous result. A headgear pulley axle made of the class of wrought iron to which axles are entitled, in which a bar, 1 in. square and 12 in. between the supports, will have a breaking stress not less than 3,500 lb., does not need great dimensions to make it strong. An axle with journals 4 in. diameter and measuring 2 ft. inside the journals will have an ultimate breaking strain of 35 tons, and would thus, with a factor of safety, 10, allow a safe working load of 3½ tons. The moral of all this is—construct headgear pulleys large, and their bearings small but strong.

Headgear pulleys should be firmly secured upon the axles. The turned axle tightly fitting into the bored pulley, and having one well proportioned and good fitting key is the best arrangement. At times, through the headgear getting on one side, or from some other cause, the axle gets out of level, and does injury. The pulley is thrown out of the vertical, and injures the winding rope in working, and disorganises the cage in the shaft. The bearings heat, and cause great resistance by excessive friction. All this must be guarded against by first fixing the pulley exactly right upon its bearings, and then by careful and regular examination keeping it right.

A headgear may be much weakened by the weight of long back stays being thrown on the main posts by struts, and pressing them out of the vertical. In some well-arranged headgears the backstays may be as much as 80 feet long, weighing several tons, and it is not enough that such long beams should merely connect to the headgear at the top, and a pillar at the bottom, placing all their central weight against the vertical posts. Auxiliary uprights should be erected to take the weight of the backstays in the middle and leave the main headgear posts unweakened to resist their proper load.

CHAPTER XI.

PIT BANKS OR HEAPSTEADS.

Requirements when Coals are brought to Bank—Advantages of two Landing Places—Use of a Drop—Appliances for Screening which are Fixed and need no Mechanical Power—Height and Formation of Stage—Extent and Arrangement of Stage—Number of Screens and Weighing Machines—Position of Workshops—Varieties of Tipplers—Forms of Screen Bars—Defective and Effective—Screen Bar Combs—Abram Collieries—Inclination of Screens—Inclination of Railways—Distance between Screens—Passing about Foot of Screens—Covered Pit Banks—Bestwood—Barnsley—Fence Gates—Appliance at Atherton Collieries—Money to be made with good Screening Arrangements—Accidents about Screens—How Caused—Suggestions for their Prevention—General Principles on which Pit Banks should be arranged.

When coals have been brought to bank the important points are:—(1.) To unload the cage and deposit the coals in the screens expeditiously. (2.) When there, to have such arrangements as will enable the needful dividing, and cleaning, and loading into wagons to be accomplished effectively and efficiently. In some cases, for the convenience of cages having two decks and to save time, there is a landing for each deck, so that both decks can be discharged at one time. Such a method not only saves time, but it avoids altogether an inconvenience unavoidable with winding drums of varying diameter. In using either a vertical drum for flat ropes or a spiral drum for round ropes we have a diameter considerably larger when the cage is at the surface than when at the bottom, and, consequently, a yard of movement for one cage means, perhaps, two yards of movement for the other cage. If all the coals, although discharged at two levels, have to be screened at one bank, it is not difficult to lower that from the higher level to the lower level by means of a "drop."

This plan is adopted successfully at one colliery with which the writer has had to do, and where the screening bank is on one level and the bank for stocking at a higher

level. Two different seams are worked, and it frequently happens that all of one mine is being loaded into wagons for sale, while in consequence of there being no orders for the other it is going to stock.

The system adopted is to raise all of both kinds to the higher level, and lower what is wanted to go into wagons to the lower level by means of a "drop."

At this colliery there are flat winding ropes, and formerly it was the practice to have in one winding rope, or rather attached to it at the cage end, a making-up piece of chain or rope, equal to the difference in height of the two landing places. This making-up piece was kept in when winding to the lower level, and was removed when winding to a higher level. The ropes and the cages worked somewhat roughly, and the unsteadiness was attributed to the action of this making-up piece. The difference between the two landings was 15 ft., and some other arrangement had to be tried. The number of revolutions to a winding was thirty, and the mean diameter of the drum was 15 ft. A length of oak packing, such as referred to in "Colliery Ropes" (see Chapter VIII.), the width of the winding rope, and in length equal to the circumference of the drum, was provided, one such piece for each drum, and being barely 1 in. thick, it increased the travel of the cage 6 in. each revolution, and as there were thirty revolutions to a winding, the total increase was 15 ft. When winding to the lower level this oak packing was removed, and when working to the high level this oak packing was put on the drum. It was simply increasing and decreasing the diameter of the winding drum so as to wind 15 ft. more or 15 ft. less.

There might be some doubt as to whether the unsteadiness of winding was really caused by the making-up length formerly used, but there was no doubt that the winding became, and continued steadier under the new arrangement.

In some cases the amount of dirt mixed with the coals sent out of the pit is so great—amounting to as much as 10 per cent.—that ordinary screening arrangements would not suffice, and special appliances, in the shape of slowly travelling bands, are introduced. In other cases there are elaborate arrangements provided for separating the fuel

into a good many classes, and revolving riddles are used, which are worked by the same engine power as is required for raising all but the round coals up to the top of capacious buildings. These being arranged with vertical divisions, provide separate accommodation for storing quantities of crank, slack, nuts, &c.

It is only intended here—in this chapter, at any rate—to deal with the more general class of screening appliances, where no engine power is needed for producing a mechanical movement, and where the coals find their way down a sloping screen into the wagon by gravitation.

Height and Formation of Stage.

Something depends on circumstances; and if, as shown on fig. 118, railways have to be excavated to a considerable depth to suit other arrangements, then the stage to its full height becomes a solid mound, and is walled in. In other cases, as shown in fig. 119, it is convenient to have the stocking ground and the lower landing about level with the tops of the wagons. This answers conveniently for discharging bricks and timber and materials generally that have to go underground, and is equally convenient for filling coals from stock.

But the more general custom, and, on the whole, perhaps, as convenient as any, is to have the lower landing level with the railways, and to have the stage built up the full height upon cast iron columns, as shown in fig. 120.

Regarding height, the efficiency of a screen should determine this, but if any mistake is made at all in this respect, the mistake should be to have too much height rather than too little. A stage too low is practically useless, whereas excess of height can very easily be prevented being injurious.

It is not only a calamity, but it is also contemptible, even viewed economically, after spending thousands and thousands of pounds in opening out a colliery, to nearly spoil the whole affair through not spending a few additional pounds to make a good high and efficient stage.

Twenty feet may be considered a minimum height, and will afford as much as from 12 to 15 ft. long of screening surface, and there should be no difficulty in separating and

FIG. 118.—PIT BANK SOLID THE FULL HEIGHT.

FIG. 119.—PIT BANK PART SOLID AND PART COLUMNS.

FIG. 120.—PIT BANK ENTIRELY OF COLUMNS.

[*To face page* 98.]

in every respect dealing properly with coals passing over such an extent of screen.

Extent and Arrangement of Stage.

The extent of stage accommodation depends upon the out-put, but in any case this is more than formerly, because the practice, which is a commendable one, of planting a smithy and carpenter's shop, in addition to weigh office and cabins, is growing. Fig. 121 gives a general idea of a stage and its equipment, calculated to deal with 500 tons of coal in an ordinary working day.

We have to arrange room enough for everything, without going to extravagance in space. We must first of all give the winding engine man a good clear view of both cages. Second, we must place the weighing machine handy for the tubs on leaving the cages, and the machine office should have an uninterrupted view of the fuel being weighed. Third, the screens must be as convenient as may be to the cages, without being too close to each other. And fourth, the workshops must be out of the way and still convenient to everything else.

One machine will do well enough with an output of 500 tons of coals in one day, but sometimes it is more convenient for banking to have two weighing tables connected to one weigh office. And also for an important pit it may be considered well to have two tables and two offices, so that in case of repairs the working of the pit may not be interrupted. In our diagram we have assumed that all the screening will be done on one side of the stage, and we have accordingly arranged for a railway for slack and a railway for coals on that side, and merely a railway for empty wagons on the other side. We have also assumed that the tubs will enter and leave the cages at the ends.

The extent of screening power depends somewhat on cleanliness and slackiness of the coals, but it is always well not to pass too much down one screen, and for such a quantity as 500 tons in one day we have provided four screens, placed in pairs, with a space of about a yard between the two of each pair.

Tipplers.

The tippler which commends itself most to the writer, of the many kinds he has tried, is the one shown in figs. 122 and 132 and screen in connection. The tub enters the tippler at the back; the tippler, without any power being required, turns towards the banksman, making a complete revolution, and having a brake attached to stop it at any point of its revolution, to enable the banksman to examine the fuel. A good tippler should require no power to turn it, should deposit its fuel easily on the screen, and should be under the easy and perfect control of the banksman. Such a tippler is the one described, and shown on figs. 122 and 132. (See Appendix, note K_1.)

Screen Bars.

The form of screen bar is of the highest importance, and the writer scarcely knows to which he has given the greater amount of practical attention—the winding rope or the screen bar. The object to be aimed at is to have such a screen bar as will allow nothing above a certain size to pass over the screen, nothing under that same size to pass through the screen, and will not choke up. We want to have no slack amongst the coal, that is unfair to the buyer; and we want to have no coal amongst the slack, that is equally unfair to the seller. Fig. 123 shows the old and abominable form of screen bar, and it is practically useless. It is flat on the top, and there is nothing to guide the fuel into the grooves; therefore some part is too well screened and another part not screened at all. Also it is of considerable depth and nearly as thick on the under side as on the top side, and consequently is nearly always choked up. Such a form of screen bar is, so far as screening fuel is concerned, "a mockery, a delusion, and a snare."

A better form, now in use at some collieries, is shown on fig. 124, and such a bar is usually made of wrought iron. Even this is only partially a good form, because the rounded upper surface soon wears flat, and thus becomes eventually, to all intents and purposes, a flat-topped bar. A really good form of screen bar is shown in fig. 125,

and such a section was no great period since advertised as being made of steel.

But whether of steel—and the writer would advocate steel as more durable, better manufactured, and not much more expensive—but whether steel or wrought iron or cast iron, fig. 125 shows the most efficient form of screen bar.

Mr. Rigg in his appliances uses steel bars made in short lengths, requiring several lengths of bars to make up the complete screen. To obtain thorough screening of all the coal the ends of one range are opposite the grooves of the next range. The system in operation at some of the East Lancashire collieries is even more complete. The alternate bars are moveable, and are continuously at work, having a combined vertical and horizontal movement. The power required is very slight and the efficiency considerable.

Screen Bar Combs.

It is found needful at times to alter the size of the spaces between the bars, or in other words, the "mesh" of the screen. Finer slack is wanted, then rounder slack is wanted, and perhaps mixture is wanted, all from the same screen. To enable this to be done expeditiously, the screen bars are fitted into combs, and these combs in their turn are made to drop freely into cast iron shoes, which are firmly bolted to the sides of the screen. If we want to change the "mesh" of the screen, the bars are taken out of the combs, the combs are lifted out of the shoes, other combs are dropped in, the bars placed back again, and the screen can resume work on a new size of fuel, after only a few minutes interval. Fig. 126 shows three different sizes of combs supposed to be intended for $\frac{1}{4}$ in. $\frac{3}{8}$ in. and $\frac{1}{2}$ in. "mesh." It is important that these combs should be well and truly made, because it is nonsense speaking of a screen as $\frac{1}{2}$ in. mesh if one space measures $\frac{3}{8}$ in. and the next to it $\frac{5}{8}$ in. Combs can scarcely be expected to be cast with sufficient accuracy, and the writer recommends their being made of wrought iron, and all the combs for one screen of the same "mesh" to be secured firmly together and slotted out by machinery. This may seem expensive, but the work deserves it. The Abram Colliery have in use a better method even than this. The combs are four-sided, the ends fitting into square boxes. Each side has a

different mesh, and therefore when changing the pitch of the bars it is only necessary to raise them up and turn the combs round a quarter or half as may be required. A good general inclination for a screen is one vertical for two horizontal. Fuel with not much slack will do with less, and fuel with a good deal of slack will do with more. Railways about screens should be so made that empty wagons will of themselves run under and loaded wagons of themselves run from other. A good deal depends upon the wagon, as a good runner will move freely with little inclination, whereas a bad runner needs pushing down a moderately steep hill. An inclination not less than $\frac{3}{8}$ in., and not exceeding $\frac{1}{2}$ in. per yard answers well. The boxes under screens for collecting the slack should be so formed as to allow the slack to leave the bars freely, and not be allowed to choke; and to prevent this choking the slack box should either always be open below, or should be arranged with a kind of "Billy Fairplay" business to open the door of itself, when a certain weight of slack has collected. The space between a pair of screens is for the purpose of ensuring that the attendants can reach right across a screen from either side, and so have command of all that passes down. Where, as is shown upon our stage arrangement, we have more than one pair of screens, there ought to be such a distance between them as will allow each to have a wagon under, and there be two clear wagon lengths between in addition. It is found a good thing all round about the screens to pave the railways, because some fuel will get on the ground, and if not paved, we either pick up some dirt, which injures the fuel, or else we leave fuel on the ground, which is waste. Whereas, with inexpensive paving all round about—old bricks will answer well enough—we can avoid both these evils, and—what is of some importance—can make the whole place look neat.

Covered Pit Banks.

At all good modern collieries the pit bank and the screens are covered in, and this is a considerable improvement. The expense is not great, the comfort to the workpeople is immense, and whereas without such protection the coals are too often in bad weather allowed

to pass over the screen into the wagon unscreened and unpicked, the covered stages enable the hands to work comfortably and efficiently in all weathers.

Two excellent examples of covered pit banks are to be found at Barrow Colliery, Barnsley, and Bestwood Colliery, Nottingham. At Barnsley the two winding pits are within convenient distance of each other, and one stage serves for both, forming one of the largest and best covered pit banks in the kingdom. The Bestwood pit bank is remarkably slight but strong in construction, and is specially made in the sides and roof to throw as much light as possible on the banking and screening.

Fence Gates.

To prevent tubs which happen to be on the bank running of themselves, or being blown into the pit shaft, the general custom is to provide fence gates, which the cage on reaching the surface raises and carries with it in its further ascent, and when the cage descends leaves the fence gates as a protection. The defect is that if a cage is drawn too high, there is nothing to prevent a tub running under the cage and falling into the pit. Mr. John S. Burrows, the manager of the Atherton Collieries, has kindly furnished particulars, given in figs. 127 and 128, of an ingenious appliance which has been at work for several years and answers admirably. The tubs cannot enter the cage or make their way to the pit top until a plank with a stud projecting upwards is pressed down. This arrangement causes no inconvenience, because the banksman in pushing the tub into the cage treads upon this plank and presses it down. This chapter has dealt almost exclusively with fixed screens requiring no mechanical power to work them. But this part of the subject would not be complete without making reference to revolving riddles and tables, elevators, and travelling bands, and attention will be paid to them further on. The next chapter is devoted to the appliances of Mr. James Rigg. There is more money to be made than many colliery proprietors would seem to be aware by good screening arrangements. We encourage the collier to make as much round and as little slack as he can in the getting, and we should continue this by having

surface arrangements which will save breakage and properly divide the fuel. Suppose a pit raising a quality of coal where the round is high in value and the slack comparatively valueless, as sometimes in the case of cannel. A bad screen, with a wide "mesh," makes a lot of valueless fuel, and still the customer is not satisfied, because all the slack does not pass through the bars. A good screen, with a narrower but sufficient "mesh," makes much less valueless fuel, and for all that the customer is better pleased, because he finds no slack amongst the round.

Accidents about Screens.

Accidents at one particular point about screens are frequent, and are avoidable. The chief cause has been the upright between the wagons, as shown in fig. 129. A wagon is being lowered under the screen, and the poor fellow who is doing so is jammed against the post.

Of late years this upright has been removed, and the arrangement introduced which is shown in fig. 130. Even this is scarcely a safe arrangement, because the horizontal timber in crossing the coal wagon is a source of danger.

The writer suggests some such plan as is shown in fig. 131, where not only is the very dangerous upright removed, but also the partially dangerous horizontal timber is dispensed with.

A good pit bank should have its parts convenient, its screens effective, the appliances safe, and the whole structure be so made that the persons employed can do their work comfortably in all weathers. These conditions carried out, every one concerned is benefited; the owner can properly separate his fuel, the customer has his fuel well-dressed, and the workman gives satisfaction to these two parties, and has comfort for himself. (See Appendix, Note K_2.)

Fig. 130.—Upright Post Removed.

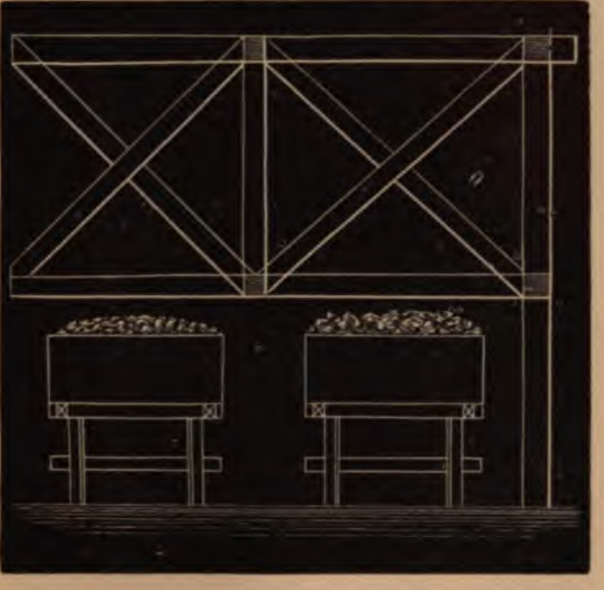
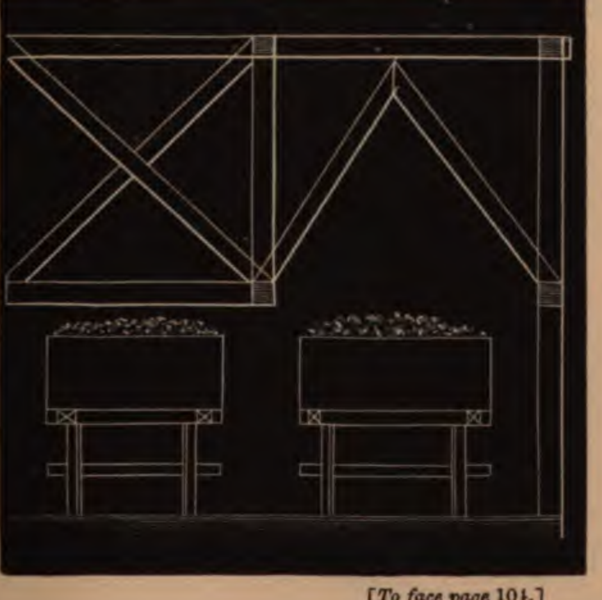


Fig. 131.—Provisions for Safety about Screens.



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CHAPTER XII.

THE TIPPING AND SCREENING OF COAL.

James Rigg's Appliances—Importance of Screening without Breaking—Tips and Screens at Clay Cross—Peculiarities of the Clay Cross Coal—System in Operation for Detecting which Tubs sent Dirty Fuel, and over which Screen it passed—Balance Screens have given best Results—Action of Balanced Screen—Tips of any Size from 5 to 30 cwt.—Material for Screen Bars—How Supported—How Arranged—Screens adaptable for Wagons, Carts, or Boats—Tips can be used for Loading Carts without Intervention of Screens—Practical Perfection of Rigg's Screening Arrangements—Large Number in Use—Profitable for Seller and Buyer—Waste of Coal with bad Appliances—Clay Cross and George Stephenson—How the Collieries came to be Opened out—Administration and Management—Singular Freedom from Accidents.

In the last chapter a description was given, with illustrations, of what were considered good arrangements for screening coals by means of fixed appliances.

So important a branch of colliery mechanical engineering demands consideration more in detail, and space will be well occupied in describing some of the very efficient machinery introduced by Mr. James Rigg, of Chester, than whom no man has striven more arduously, and, on the whole, more successfully to provide means for ensuring a maximum effectiveness in tipping and screening.

The writer having been practically connected with that part of colliery operations which deals with coals after they have been got, is able to bear strong testimony to the importance to proprietor and customer of despatching fuel with high screening efficiency and facilities for thorough dressing with a minimum of breakage. It was not desirable that such a matter should be dealt with on insufficient information, and, unfortunately, the screening appliances to be described in this chapter, although extensively used in many parts of England, have not, as yet, made much headway in the county Palatine. This is

simply a question of time, and necessity (which is not only the mother of invention but the cause of most improvements) will compel proprietors in all parts to introduce improvements in their screening arrangements. A favourable opportunity has recently been afforded to the writer of making himself thoroughly acquainted with combined tips and screens as efficient as any now in use, and of vigorously renewing an acquaintance made several years ago with Mr. Croudace, the manager, and of commencing an acquaintance with Mr. Howe, the engineer of the Clay Cross Collieries. At these collieries three sets of Rigg's patent tips and balanced curved screens have been in operation some time, alongside several working upon the old principle. The particular seam worked where these appliances are placed is very valuable, and fetches a high price in the London market. But the coal is as tender as it is valuable, and, like most others, is not, as worked, absolutely free from inferior matter. It is essential that this coal should be dealt with gently in tipping, so as to make as little slack as possible and as much round coal. Also that it should be thoroughly screened and picked, so as to leave nothing but good clean coal upon the screen. The last requirement is that the coal should be deposited in the wagons without breakage. It is not too much to say that these conditions cannot be fulfilled, and are not fulfilled, with ordinary fixed screens. So impressed are the Clay Cross authorities with the vital importance of dealing with the coals properly on reaching the surface that a system is in operation which may possibly commend itself in other parts of the country. Every tub is numbered, and a record is kept of the numbers tipped into each screen and into each wagon, so that should complaint arise, it is known exactly with which tubs and at which screens any wagon was loaded. (See Appendix, Note L_1.) Having fixed screens and balanced screens at work side by side, no better test could possibly be had as to their respective merits, and at Clay Cross the balanced screens have proved themselves the most profitable to the proprietors, and the most efficient to the customers.

We now offer some illustrations and descriptions of what has proved itself to be a very efficient method of tipping and screening, and first we deal with the tip,

FIG. 133.—ELEVATION OF RIGG'S TIP
SCREEN.

FIG. 134.—ELEVATION OF RIGG'S TIP DISC

[To face page 107.]

the object of which is to discharge the coals quickly without breakage, and this is accomplished by the tip as shown, which is constructed to deposit the coals upon the bars without injurious velocity or fall. The next point is to receive the coals when tipped upon screen bars, which will effectually allow the slack to pass through and retain the round coal upon the bars. The wrought iron shoot in which the screen bars are placed can rotate to such an extent as to invert itself when coal is being tipped at such an angle as just to move over the bars; and, to make this action clear, the sketches show the appliances in various positions, sketch No. 133 showing the manner in which the coal tub is retained within the tip. The tips, whether made for tubs containing only 5 cwt. or as much as 30 cwt., are exactly balanced and self-acting in their forward and return movement, and under the easy control of one man. They deposit the coal upon the plate at the higher end of the screen, from which it passes gently on to the bars, thus ensuring a more perfect separation of the qualities than is possible with tips which simply throw their contents in a mass upon the screen bars. The sketch shows the tip half inverted into the screen, but retaining the coal. Sketch No. 134 gives an illustration of a double-fixed screen which is composed of metal throughout, the sides and hoppers being iron, and the screen bars of a special section of steel, combining lightness and strength. These bars are supported upon plates cast in leaves, and between improved variable dividing plates, enabling the pitch in the distance between the bars to be easily altered to suit the different seasons and varying requirements of the markets. Sketches 135, 136, and 137 show in perspective and side elevation each position of the tip and curved balance screen, to which special attention is directed, because it meets more completely than any other arrangements the objections to fixed or balanced screens for tender coal requiring picking, also because it delivers the round coal nearer the floor of the wagon than any other, and it leaves the screen at a pace only sufficient to overcome friction, thus entirely obviating the breakage due to the velocity at which round coal leaves fixed screens. This remark applies equally whether there are fixed platforms or doors at the ends of such screen or not.

The sketches, Nos. 135, 136 and 137, with sufficient clearness explain the action of this curved balance screen. The main body of the screen carrying the bars is curved, and is carried upon a square shaft supported upon bearings on the framework. This screen oscillates through an arc of from 15 degs. to 20 degs., sketch No. 136 showing it receiving the coals from the tip, and No. 137 showing the coals being discharged into the wagon. The angle at which the bars are placed when receiving the coal just exceeds the angle of friction of the coals to be dealt with and the lower bars are almost horizontal. The coal distributes itself upon the lower bars, and enables the man working the screen to detect at sight any refuse, which he places upon the platform without needless labour or delay. As gravity causes the screen when empty to assume its normal position for receiving coals from the tip, so, on the man releasing the brake on the screen shaft, gravity preponderates towards the other end, owing to the weight upon the lower bars, and alters the position of the screen so as to deposit the round coal high or low, *just* as the wagon is nearly empty or nearly full. A fixed hopper under the screen conveys the slack either into separate wagons or on to travelling bands as may be required. The steel bars are also supported between the improved variable dividing plates, and placed in short lengths, each successive range of bars corresponding with the spaces of those next them, so compelling all the slack to pass through. It will be seen that this screen, in addition to its other advantages, is self-acting in both directions, and avoids the necessity of persons standing upon the round coal after its discharge into the wagons, making fruitless endeavours to detect and remove impurities. This also avoids a minor, but harassing ground of difference between the coal proprietor and the men who are responsible to him for the quality of round coal loaded in the trucks. These screens are also adaptable for canal boats, and a range of four will load a boat very rapidly. In loading wagons the screens may be used in pairs or singly. And at collieries where a considerable quantity of coals is carted a single balanced screen is as efficient to load a cart as to load a wagon. Where no screen is necessary and the coals have to be tipped into the cart direct, the tip itself is effective in

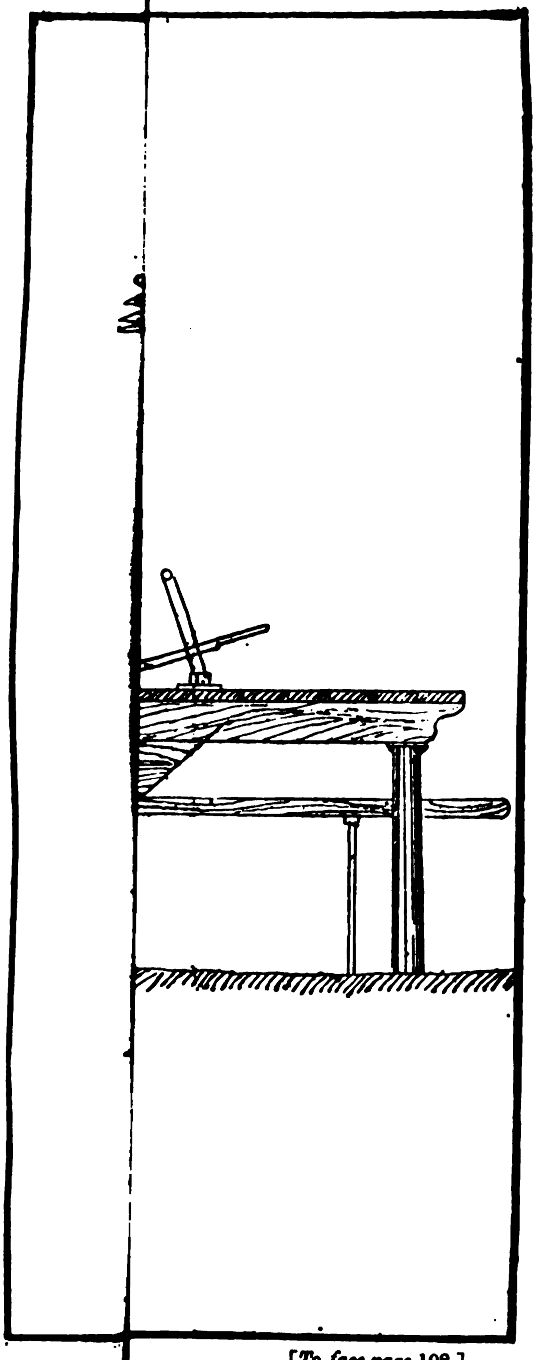

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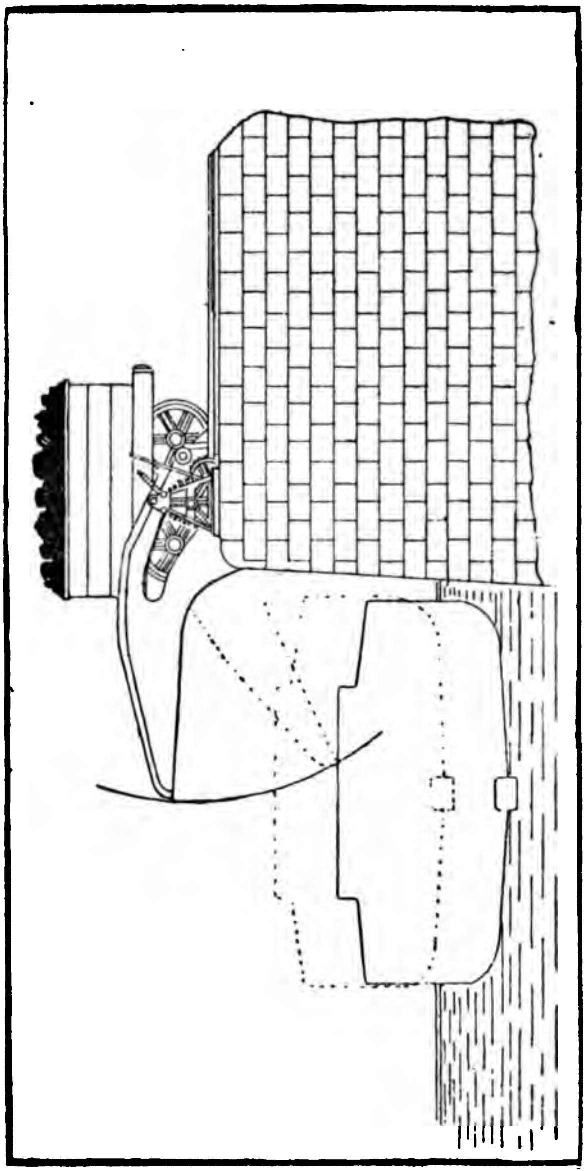
FIG. 139.—RIGG'S TIP FOR LOADING CANAL BOATS.



[To face page 109.]

loading the cart from the bottom to the top without breakage. The foregoing forms an imperfect description of what the writer is convinced, from personal observation, is as efficient a mode of screening as any now in use. That many colliery proprietors realise this already is proved by the fact that many hundreds of them are in use, and their introduction almost generally is inevitable, first in the interest of the customer, who insists, as he has a perfect right, to have his coals free from slack—which cannot be accomplished with fixed screens—and free from impurities, which should be dealt with before reaching the wagon; second in the interest of the proprietor, who will make a profit out of round coal, but has no chance with such a ruinous proportion of slack. At very many collieries in England nearly as much slack is made as round coal, and which in some cases is valueless, and in every case sells at a low rate. Sketch No. 138 illustrates an application of the patent tipping machine receiving coal from the lower end of the screen, and delivering it into carts, and in a remarkable degree avoids the great breakage usual at land-sale collieries. The round coal is delivered just clear of the floor of the cart, gravity under control of the brake working the tip in either direction. The last of our series of sketches (No. 139) illustrates the application of rotating shoot to the patent coal-tipping machine for loading from railway trucks into barges, and which can be equally applied in tidal and other docks. It is shown in this case supported upon masonry, but may also be worked upon balanced platforms.

The appliances dealt with in this chapter serve the purpose of the proprietor by enabling him to sell a larger proportion of round coal, and meet the requirements of the customer by giving him round coal free from slack and impurities. Mr. James Rigg, of Chester, having devoted nearly a lifetime to this class of machinery, seems to have reached practical perfection, and deserves, and will obtain, substantial results. For the opportunity of testing the efficacy and for facts as to actual results, extending over a considerable period, the writer is indebted to his friends, Mr. Croudace and Mr. Howe.

Clay Cross has always possessed a fascination for engineers. That grand old father of the profession, George

Stephenson, in cutting the railway tunnel, noticed the outcrop of coals, and opened these collieries in consequence; and it is in keeping with his persevering energy and ability in effecting improvements, which developed old industries and generated new, that the collieries with which he was so intimately associated should have been in our day ready to adopt improvements in the tipping and screening of coal.

This chapter can hardly conclude without an expression of pleasure at the excellent administration and management of the Clay Cross Collieries. For seven years one important pit has experienced no fatal accident, and another equally important pit was free for eleven years. Long may Clay Cross be famed for the safety in getting and efficiency in screening coal. (See Appendix, Note L_3.)

NOTE.—The terrible disaster, for which after careful investigation, it was decided that no blame attached to the ownership or the management, happened after the publication of the first edition.

CHAPTER XIII.

STEAM BOILERS FOR SURFACE AND UNDERGROUND.

Externally Fired Boilers—Cornish—Lancashire—Root—Howard—Boilers generally used at Collieries—Neglect in Design and Construction of Boilers—The average Steam Engine Maker and Boiler Maker, a contrast—Requirements of a good Colliery Boiler—Materials used in Construction—Shape of Boilers—Advantages and Disadvantages of Externally-Fired Boilers—Boiler Seating—GallowayTubes—Dimensions of Boilers—Tensile Strength—Ductility—Weakening of Plates with any kind of Riveting—Oval Rivets—Thickened Plates at Joints—Weakness of Horizontal Seams—Strength of Ring Plates—Lap Joints—Butt Joints—Single Riveting—Double Riveting—Proportions of Riveted Joints—Reason for Double Riveting Horizontal Seams—Drilling and Punching—Mechanical Riveting—Advantages of Drilling—Advantages of Mechanical Riveting—Mr. W. R. Browne on Proportions and Strength of Riveted Joints—Diameter of Rivets—Lap and Pitch in Single Riveted Joints—Lap and Pitch in Double Riveted Joints, whether Chain or Zig-Zag—Chain Riveting the Best—Suggested Diagonal Joints—Increased Strength with Diagonal Joints—Weakness of Flat Ends and Internal Flues—T-iron Rings—Adamson's Flanged Seam—Expansion Hoop—Securing End Plates to Barrel—Gusset Stays—General Arrangement of Mountings—Advantages of Galloway Tubes—Fox and Hopkinson's Corrugated Flue—Increase in Strength and Heating Surface—How Boilers should be made—Plates Thin with High Tensile Strength and Ductility—Large Heating Surface—Tested to Double the Working Pressure—John Windle, of Newton Heath, on Ring Plates—Size they can be made—Practical Results at Barrow.

Form and Construction.

This chapter will deal only with the boilers in general use for colliery work, namely, the cylindrical and egg-ended boiler externally fired, the Cornish boiler with one internal flue, and the Lancashire boiler with two internal flues. Other boilers have been tried here and there, such as the "Howard" and the "Root," the great principles of which are rapid generation of steam and great strength, with not much thickness of material. They require good water

and vigilant attention. The small tubes soon become choked, and steam is quickly up and quickly down. But such boilers are not likely to come into anything like general use for colliery purposes, and the space we propose to occupy will be better devoted to such boilers as are in general use. The subject will be divided into three parts; (1) the form and construction, (2) the equipment and the seating, (3) explosions. And at the close of the chapters a few practical rules as to strength of boilers will be given.

It is remarkable how little thought has in years past been devoted to the steam boiler as compared with the steam engine. Even the workmen engaged seem to be of different classes. The average steam engine maker is an intelligent man with a fair education, attends scientific lectures, and has some knowledge of drawing. The average boiler maker too often is a somewhat rough member of society, on whom education seems to have made little impression. Every care is exercised in designing and making engines with a view to their efficiency and economy, whilst too often the boiler is a careless construction of bad material. There is, of course, not nearly so much scope for a man's ingenuity and inventiveness in the boiler as in the engine, but the boiler is the steam generator, and at least as much economy can be effected there as in the engine, and besides, boilers may and do cause loss of life and destruction of property, as well as waste of fuel. A steam boiler for colliery use, whether below ground or above ground, should be not likely to get out of order, made of good material, and of proper construction, should be a ready steam generator, should have its work well within its capabilities, should be properly seated and well equipped, and be so protected as to avoid condensation of the steam generated.

It would be interesting, if this were an historical article, to show how boiler makers tried as a material, wood, and stone, and copper, and cast iron, and gradually got to wrought iron. And as to shape, how step by step the cylindrical form was reached. It is not an historical article, and it will be sufficient to say that now all good colliery boilers are made of either wrought iron or steel, which is simply superior wrought iron, and are cylindrical in form. Fig. 140 shows the cylindrical externally-fired

boiler; fig. 141, the Cornish boiler; fig. 142, the Lancashire boiler. The cylindrical externally-fired boiler with circular ends is strongly made, but it is not economical, because it possesses proportionately a small heating surface, and the heat gets away to the chimney without being utilised. This difficulty is overcome, to some extent, in the North of England, by having very long boilers, in some cases as much as 70 ft. or 80 ft.; but they occupy an enormous space, and very long boilers are not desirable. And in the externally-fired boiler a great deal of the heat never gets near the boiler, but heats the brickwork of the seating and the ashpit below. The Cornish boiler is an improvement, because it presents more heating surface, and therefore economises the fuel. The Lancashire is simply a Cornish boiler with two internal flues instead of one, and with the Galloway tubes, now almost universally used, is a popular colliery boiler, and renders excellent service. The cylindrical egg-ended boiler, and the Cornish, do not often exceed 6 ft. diameter, but the Lancashire is usually 7 ft. or 7 ft. 6 in. As to the construction of boilers, the first point is as regards the plates, which should be high in quality. No boiler, however well designed, can be a good boiler if made of defective plates. No plate should be put into a boiler possessing less tensile strength than 20 tons per square inch, and to ensure this, the plates, that is specimens from them, should be tested, both for tensile strength and ductility. Having secured good plates, there comes the work of putting them together, and however this is done we get a weaker structure than if made of one plate. It has been determined by eminent authorities that the best system of riveting weakens the plates one-fourth, and the ordinary system of riveting nearly one-half. Various proposals have been made with a view to avoiding, or at any rate lessening, the weakening. Oval rivets have been tried, and with good results. (See fig. 143.) The plates have been thickened at the joints, and this has produced a good effect. (See fig. 144). But the effective plan would seem to be dispensing with the joints altogether—at least the horizontal joints, and constructing the plates in complete rings, like tyres and hoops. So long as we retain horizontal joints and make each ring of several plates we can scarcely have a truly circular boiler, and the slightest

departure from a true circle has a weakening effect. Objection has also been taken to the usual method of making the circular joints, as shown in fig. 145, because one part of the shell is made larger in diameter by twice the thickness of plates, and joints have been proposed as shown in fig. 146.

A good deal of attention has been given to the matter of riveting; and, bringing it into few and simple words, the results would seem to be as follow:—First, single riveted joints, as shown in fig. 147, weaken the plate nearly one-half; double-riveted joints, as shown in fig. 148, weaken the plate quite one-fourth. Second, the proportions of a good riveted joint are—the rivets to have a diameter equal twice the thickness of plates; the lap of a single riveted joint to be three times the diameter of the rivet; the lap of a double-riveted joint to be 5½-6 times the diameter of rivet; the pitch of the rivets to be three times the diameter in a single-riveted joint, and 4½ times the diameter in a double-riveted joint. All horizontal seams to be double-riveted. This provision as to double-riveting the horizontal seams is because, as will be shown hereafter, the boiler is weaker to resist pressures acting diametrically than pressures acting longitudinally. Good modern boilers have their holes drilled, not punched, and the riveting done by mechanical power. There can be no question that better holes can be made and more accurate work accomplished with the drill than the punch, because the drill cuts the hole out cleanly and without strain upon the surrounding parts of the plate, whereas the punch forces one part of the plate away from the other, and distorts the hole and the plate. And as regards the riveting, mechanical power strikes the iron while it is hot, which is as important in boilermaking as in smith work, to which the proverb is more frequently applied.

In an able paper to be found in the Transactions of the Institution of Mechanical Engineers for 1872, Mr. Walter R. Browne, then a member and now the secretary of that body, goes very elaborately into the proportion and strength of riveted joints. For single-riveted lap joints the proportions are—diameter of rivet = 2 times thickness of plates, lap = 3 diameters, and pitch = 3 dia-

meters. In double riveted lap joints there are two kinds, viz., zig-zag and chain, of which Mr. Browne says the latter gives the strongest joint, and lays down the following proportions:—The diameter of rivet = 2 times thickness of plate, the lap = 5½ diameters, the distance between the pitch lines = 2½ diameters, and the pitch = 4½ diameters. For zig-zag riveting the proportions given are—diameter of rivet = 2 times thickness of plate, lap = 6 diameters, the distance between the pitch lines = ¾ the pitch, pitch equal 4½ diameters. In the same paper attention is drawn to the method of strengthening boilers by having diagonal joints. Mr. Browne says that taking the angle of joints at 45 deg. the effective strength of the boiler and the joint is increased in the ratio of 4 to 5.

So much for riveting, and as concerns the externally-fired boiler that is about all. But with the Cornish and Lancashire it is different; we have still the flat ends and the internal flues to contend with. At first these internal flues were a difficulty and a defect, because they collapsed in consequence of their great length, with much less pressure than was required to burst the boiler. To remedy this, T irons, as shown in fig. 149, were introduced, and answered well enough against collapse, but made no allowance for expansion. Mr. Adamson then gave us his flanged joint, as shown in fig. 150, which provided both the needful stiffening and allowed some expansion as well. The difficulty was not altogether overcome till the introduction of the well-known hoop shown in fig. 151, which provides plenty of strength, and allows the freest scope for expansion and contraction. Now as to the flat ends, which are troublesome, because if not stiffened they are weak proportionately to the boiler. The back end is almost invariably secured to the shell, as shown in fig. 152; but the front end is often joined as shown in fig. 153. These end plates, in well-made boilers, are bored to receive the internal flues. The weakness of the flat ends is overcome by the addition of gussets, shown in figs. 154 and 155, and also by longitudinal stays running right through the boiler, and secured inside and outside at both ends. Fig. 156 gives generally the construction of a short Lancashire boiler, and shows the various mountings to receive

the valves, &c., of which something will be said in next chapter. But we ought to include the Galloway tubes, shown in figs. 157 and 158, which give a threefold advantage to a boiler. First, they add to the heating surface; second, they split up the heated gases in their passage, and compel them to act more upon the plates of the flues; third, they not only allow but ensure a freer circulation of the water, which assists steam generation, saves fuel, and increases safety. Still another improvement has been added quite recently for strengthening flues and increasing heating surface, namely, the Fox and Hopkinson corrugated flue, as shown in fig. 159. Experiments have demonstrated that this flue is at least four times as strong as a plain tube of same diameter and thickness of metal; and it is a simple matter, which can be proved by measurement, that the corrugated flues present one-fifth more heating surface than plain flues. That these corrugated flues are coming rapidly into use is proved by the fact that, although a comparatively recent improvement, already miles of them have been made. They do seem an unquestionable improvement, and can be attached to any internally-fired boiler instead of the plain flues. Great economy will be and ought to be effected in the working results of boilers, but no economy should be attempted in their construction. The steam boiler is to all intents and purposes part of the steam engine; and although of late years we have for convenience separated them, the fact remains that the one generates the steam and the other uses the steam, and the best economy is that which commences with the boiler and is continued in the engine. We should make our boilers of strong thin plates; strong to resist pressure—and for this steel has been successfully used, enabling either the pressure to be nearly doubled, or the thickness diminished almost one-half. Thin, because the heat will pass through better, thus generating steam quicker and damaging plates by heat less. As large an amount of heating surface as possible should be presented, so long as that heating surface is all below the water level, and the construction of the boiler should be such that the water has good circulation. Whatever pressure it may be intended to work the boiler with steam, it should be tested to double that pressure, by hydraulic

power betore leaving the boiler shop, and should be closely examined whilst under this hydıaulic test to see that there is no leakage and no bulging out of the flat ends. (See Appendix, Note M.)

While this chapter was preparing for the press, some interesting letters were received from Mr. John Windle, of Newton Heath, from which the following is an extract:—" I venture to write you on the subject of ring plates for boiler construction. Have been trying to get steel makers to put down a mill for rolling such plates for over twelve months. Am the patentee of such a mill, and purpose to roll from 2 ft. to 14 ft. diameter, and 4 ft. wide. It is very hard work to get people to believe in the utility and practicability of these proposals. Have experimented at Barrow Steel Works, and succeeded in rolling a ring 4 ft. 6 in. diameter, 18 in. wide, and ½ in. thick."

CHAPTER XIV.

STEAM BOILERS FOR SURFACE AND UNDERGROUND.

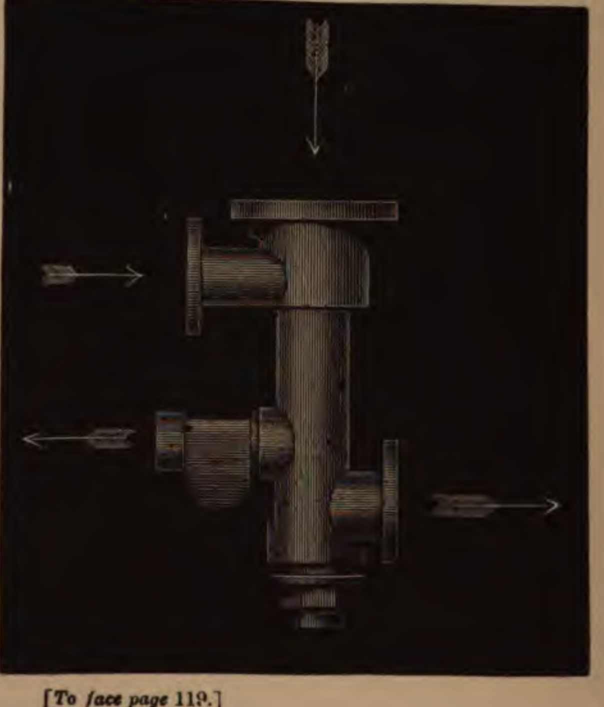
Underground Boilers should be carefully fixed—Underground Boiler-houses should be roomy, Height above, and Space all round—Arches sometimes give way, therefore should have great Strength—Side Pressure will distort the Boiler unless there is sufficient Clearance—Advantage of Passage for Cool Air—Spare Boiler should be provided—Exhaust should be piped away—Feed Water should be heated—The Exhaust Injector—Attendant should be able to go on Top of Boiler to examine Mountings—Damper and Feed should be worked from Front—Equipments of a Boiler—Safety Valves—Defective Forms—Cowburn's Dead-weight Safety Valve—Hopkinson's Low-water Safety Valve—Their Advantages—Requirements of a good Safety Valve—Getting up Steam and laying a Boiler off should not be done too rapidly—Damage to Boilers—Value of Efficient Firemen—Surface Boilers—How seated —Fire-brick exposed to Action of Fire—Brickwork between two Boilers —Flue Arrangements—Size of Flues—Inspections—Wrought-iron and Cast-iron Mountings—Domes and Receivers for Steam—Bend in long Steam-pipe Range—Inclination of Steam-pipes—Object of Separator—Support for Steam-pipes—Feed Water—Feed Warmers—Scumming Arrangements — Dervaux — Feed Valve — Steam Valve — Expansion Joints—Furnace Mountings—Fire Doors—Ventilating Grids—Fire-grate—Heating Surface—Horse-power—Fuel consumed—Covering for and Roof over Boilers—Chimneys—Various Forms—Chimney Top—Height and Area—Foundation for Chimneys—Smoke Prevention—Juckes's Furnaces—Methods of Application—Mechanical Stokers injecting Powdered Fuel—Thomas Morris, of Warrington, on Smoke prevention—Lavington Fletcher's Experiments at Wigan—Generating Steam with Waste Heat from Coke Ovens—Hetton—Bear Park—Barnsley—Langley Park.

UNDERGROUND.

MORE care is needed in fixing a steam boiler underground, and we will deal with that first. Boiler houses have to be prepared, and in doing so two special points should be observed. The arching of the house should be strong enough, otherwise it will give way and fall in upon the boiler. This is very important, because in many cases where a boiler is placed underground the whole pit depends upon it, and anything happening to the boiler or boilers stops the whole place. This arching

Fig. 160.—Boiler House Underground.

Fig. 161.—Exhaust Injector.



[To face page 119.]

should be high enough not only to allow room for mountings and their examination, but also to lessen the injury which steam will do to the brickwork. The other point is that there should be such width that the sides of the arching will be free from the boiler seating. In fact a clear passage should be left if possible on each side, sufficient for a walking way. (See fig. 160.)

Too much stress cannot be laid upon these two points, because arches have given way underground, and caused damage and stoppage of work. And in some cases so far from allowing passage between the brickwork of the seating and the brickwork of the arching, the two have been built as close together as possible. The result has been that the sides of the house press in, the brickwork of the seating expands, and the boiler is distorted, having its height increased and width diminished, and losing its circular form, is dangerously weakened. This clearance is also an advantage, because it allows a passage of cool air, which prevents heat striking through the archwork and setting fire to any coal there may be in the vicinity. A steam boiler placed underground should, on the one hand, be kept as close to the upcast shaft as may be, to avoid the length of flue and proportionate danger of fire there would otherwise be. And, on the other hand, should not be far from the steam engine. This means, of course, that in all cases where possible, engines fixed underground should not be far from pit bottom. A good supply of water should be kept handy, to allow the hot ashes to be quickly cooled at will, and extinguish anything having a tendency to heat. Wherever one boiler is sufficient for the work underground there should be two. If only one, the boiler is very likely to be overworked, and some day there will be an accident, and the pit will be thrown idle. It is not necessary both should be in one house, provided each is convenient to the pit shaft and the engine. But in any case there should be a spare boiler for cleaning and for repairs. In underground boilers the steam should not be allowed to roar out upon the arching, but should be piped away into the shaft. One difficulty with underground boilers is heating the water, because if taken from some part of the workings or between the pit bottom and top, it is not easy to do it. When the feed-water is taken,

as in some cases it is, from the surface, it can pass through the usual surface feed warmers, and carries at least some heat into the boiler, but this is only trifling. The difficulty of heating the feed water for underground boilers would seem to be removed by the recently introduced "Exhaust Injector," of which an outside elevation is given in fig. 161. It really does seem a marvel of simplicity and economy, and is making great headway. It works and feeds the boilers to which it is attached with exhaust steam only, and for boilers underground will be efficient in several ways. It will save the steam otherwise needed to work the feed pumps where the water does not run in by gravity. It lessens the amount of escaping exhaust, which is not a desirable thing, either in the pit or pit shaft. It heats the feed-water almost to boiling point. This appliance is not expensive, can easily be fixed, needs next to no attention, and having no working parts in motion is not liable to get out of order. (See Appendix, Note N_1.) Every underground boiler should be so arranged as regards room and air that the attendant can go on the top to examine it, but it is as well to enable the attendant to do a good deal without leaving the fire-hole. The damper and the feed should be so arranged that they can be regulated from the fire-hole. The equipments of a boiler underground will not differ from a boiler on the surface. Each underground boiler should have at the front a damper arrangement, a feed valve, two water-gauge glasses, a steam gauge, a man-hole, a blow-off, and a fire door or two fire doors, according as the boiler is Cornish or Lancashire, adapted to lessen or increase the amount of air passing into the furnace. On the top there should be one safety valve on the dead weight principle, one safety valve on the low water principle, one steam junction valve, one scumming arrangement, and one man-hole.

Safety Valves.

These had better be dealt with under this heading, "Underground Boilers," because whilst we want safety everywhere, we are, or ought to be, more anxious to adopt appliances to obtain safety underground than elsewhere. Safety valves are the most important fittings of

Fig 162.—Section of Cowburn Safety Valve.

Fig. 163.—Elevation of Cowburn Safety Valve.

Fig. 164.—Cowburn Group Valve.

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any boiler, and the usual type of valve, with long lever and weight at the end, is safe only in name. The objections to it are that, whether the valve fits in the seating with wings or with a spindle, the valve is liable to stick, and the explosion some years ago on the warship "Thunderer" was attributed to the safety valve sticking. And no blow-off pressure can be arranged, as this class of safety valve will at times commence blowing off before the proper pressure has been reached, and in all cases will allow the pressure to rise after this pressure has been attained. This means that we cannot even rely upon the blowing-off pressure fixed upon, and run the risk of the boiler working at any time 5 or 10 lb. above the intended blowing-off pressure. And the long lever arrangement affords temptation for being tampered with. A really good safety valve is a necessity of all steam boilers, and should fulfil the following requirements:—(1.) There should be no chance of sticking. (2.) No steam should blow away until the fixed pressure has been attained. (3.) The pressure should not be allowed to rise beyond this fixed point. (4.) It should not easily be tampered with. The very best safety valve for fulfilling these requirements is the Cowburn dead-weight safety valve, introduced a good many years ago, on the principle as shown in figs. 162 and 163. An improvement upon this valve has recently been made and without increasing the cost, and is called the Cowburn group valve. It possesses all the excellence of the original valve, occupies less space, is neater in appearance, and prevents more lip opening for escape of steam with less weight. Every boiler should have a Cowburn dead-weight safety valve, or one which effects the same useful purposes, and all purchasers of boilers should so stipulate. Fig. 164 gives an idea of the Cowburn group valve in plan. Perhaps the strongest argument in favour of these valves is that thousands of them are in use. The writer would advise their application to all boilers, but more especially to boilers underground.

Sometimes a boiler is injured because the water is allowed to get too low, and the plates become so weakened by being hot that the pressure bursts (not immediately but at some future time) or injures the boiler.

The remedy for this is a safety valve which, acting as an ordinary valve to blow steam away when the pressure is too high, will also open and blow all the steam off when the water falls below the correct level. The valve which has answered this purpose best we owe to Messrs. Hopkinson, of Huddersfield, which either has or has not, as required, an alarm whistle attached, to warn the attendant when the water is getting too low. This alarm also is a useful contrivance enough when kept in working order. The writer has had no experience of the alarm, but can speak to the efficiency of the low water safety valve. The action is very simple. There is a lever inside the boiler to which is attached a float, so that when the water falls the float falls also, and this raises the valve and allows the steam to blow off.

In putting on or putting off underground boilers the great height of the chimney producing the draught must not be forgotten. It is not a matter of 40 or 50 yards, but in many cases ten times that height, and the keenness of the draught thus produced may prove serious. The boiler should be got under steam slowly, and the steam let down at a week end quite as gradually. The writer had a case in which, to save a few minutes, the whole operation of knocking a boiler off was gone through very quickly, and the result was cold air rushed through and cooled the boiler, whilst the brickwork of the boiler remained almost red hot. The hot seating gripped firmly the cooling and contracting boiler, and the boiler came in two at the middle. There is just a point as to firemen at boilers underground. The writer has long been of opinion that firemen at boilers are not a sufficiently skilled class of men. Any labourer is considered good enough to use a spade and throw slack on to the bars, and consequently the rate of wages paid to firemen is low. But is it true economy to put an inefficient man to fire at any boiler? He may do £100 worth more damage to the boilers under his charge in the length of a year than an efficient man; and a bad fireman will certainly use more slack to do the same work than a good fireman; but in any case underground boilers should have competent men with some knowledge of the principles and construction of the boilers they have charge of, and also some knowledge of how to

FIG. 165.—TWO LANCASHIRE BOILERS.

FIG. 167.—SPRINGING PIPE AND STEAM RECEIVER.

FIG. 166.—STEAM RECEIVER.

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avoid alike mishap or disaster. Boilers underground are under the eye of fewer competent people than those on the surface, and the firemen underground should either be better men, or else the general standard of firemen, both above ground and below ground, should be raised. Men who do not know the danger of overloading safety-valves—who will keep on firing an almost empty boiler without noticing that the water is running out as fast as it is put in—men who when a boiler is off for cleaning and repairs do not know when all the joints have been made and the proper openings closed, are not the men to have charge of boilers anywhere, and certainly not underground. Probably the time is not far distant when the law will direct that enginemen and firemen shall pass examinations, and only hold their appointments by certificates of competency as colliery managers do now.

SURFACE.

Externally-fired boilers are often seated by having cast-iron brackets riveted on the sides, and these brackets rest upon the brickwork seating. This is not the best possible way; the boiler and the brackets seem to get fast in the seating, and when the boiler is knocked-off for cleaning the contraction is not properly provided for, and the plates to which the cast-iron brackets are riveted become torn. A better plan would seem to be to place the boiler on saddles fitted with rollers, or to swing the boiler from brackets bridging it, which would allow the boiler to freely expand and as freely contract. A defect in the seating of an externally-fired boiler is that the sides of the hot brickwork are close up against the boiler, and plates along this part being more heated or kept heated at times when the other parts are not, are liable to injury. A boiler, whether externally fired, or Cornish or Lancashire, should have all the parts of the seating exposed to the action of the fire of good firebrick, and when several boilers are placed side by side the walls between should be sufficiently thick to allow the removal of any one boiler without inconvenience to its neighbour. Fig. 165 shows an arrangement of two boilers. There is a difference of opinion as to how boilers should be seated—whether inclining to the front or the back. To have them set absolutely level seems a good

arrangement, and any sediment which collects in spite of the appliances must be carefully removed at the times set apart for periodic cleaning. Externally-fired boilers in many cases have only an under or flash flue. Cornish and Lancashire have the internal flues through which the heated gases pass to back end, then an under flue through which the heat returns to front, and a flue on each side along which the gases make their escape to the chimney. This bottom flue and the side flues should give room for a person to enter and make inspections; and the side flues should be so made that no heat can act upon the boiler above the water level. A fair arrangement of flues is to make the under flue equal in width to the radius of the boiler, and 2 ft. deep, and to have the side flues 6 in. wide at the narrowest point, and as high as crown of flues, and as low as firing-floor level. (See Appendix, Note N_2.)

Mountings.

The branches placed upon boilers were formerly all cast iron, but they cannot be recommended. If not exactly the shape of the boiler they are liable to break in securing, and are not easy to caulk. Wrought iron mountings are very popular. They are stronger, lighter, and more pliable, and more easily caulked. Steam domes are not so general as they were. They weaken the structure very much, and are awkward if the boiler has to be moved. A better plan seems to be, in the case of a range of boilers, to have no domes, but a receiver of considerable dimensions running across them all. In this way great storage capacity for steam is provided. (See fig. 166.) The steam pipes can be attached to this receiver at any point, and on the top is best, as it makes it more difficult for the water to rise along with the steam. With separate branches steam can be conveyed to any winding or hauling or pumping engine in separate ranges. When the steam-pipe has a considerable distance to travel to the engine, it should not be taken in a direct line, but should have at least one bend, to give it elasticity, which is much better than introducing expansion joints, which are not reliable. Steam pipes should either be level from boilers to engine, or inclined towards the engine, and separators may be placed between the boilers and the engine to prevent the water, from con-

Fig. 168.—Steam Pipes over Railways.

Fig. 169.—Feed Water Warmer.

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densation of the steam, passing into the cylinders. The large railway requirements of large collieries make it necessary that the boilers shall be some distance from the engines, and some neat contrivances have been introduced for supporting the pipes over the railways without the intervention of dangerous uprights between the roads. (See fig. 168.) [For this sketch the writer has again to acknowledge the courtesy of his friend, Mr. C. F. Clark, of the Garswood Collieries.] Formerly, feed-water was introduced into boilers cold, and the feed-pipe entered from the top and delivered through an open-ended pipe close to the bottom. This was injurious, because the water was cold, and the delivery was concentrated. Feed-water should be hot, and should be distributed. Good practice now consists of sending the feed-water in hot from the front, through a horizontal pipe a little below the water level and having a closed end, and the pipe perforated on the upper side, so as to throw the water up in the form of spray. (See Appendix, Note N_3.)

Many appliances have been adopted for heating the feed-water with the exhaust steam, perhaps the most common being to use an old boiler into which the exhaust was delivered below, and the feed-water above. The exhaust heated the feed, and the feed condensed the exhaust. (See fig. 169.) The advantages of this arrangement are: it is cheap, and it uses the same water over and over again. The disadvantages are: that two pumps are needed, one for hot and one for cold water, and whatever grease and dirt come from the cylinders go into the boilers and into the cylinders again. Mr. Unsworth, manager of the Scot Lane Collieries, pointed out to the writer an arrangement which avoids both these disadvantages. The feed-water passes through the feed-warmer in a considerable length of rising and falling piping, and by this means the feed is heated and the exhaust condensed without the two mixing, and one pump does all the work of passing cold water into the warmer and hot water into the boilers. The exhaust injector already referred to will probably ere long supplant many existing feed arrangements, because it needs no pumps and no warmer, and utilises as its power what hitherto had not been utilised at all—namely, the exhaust from the

engines. The difficulty has been raised that depending on exhaust it can only work when the engines are working, and it would be awkward to have to start large winding engines simply to work an exhaust injector. This verily would be a "mountain in labour bringing forth a mouse." But it may be arranged to feed the boiler when the engine is standing. The water used for steam generation often holds in mechanical combination a considerable amount of impurity, which is liable to deposit upon the bottom of the boiler, and thus assist in the destruction of the plates by allowing the heat to burn them instead of passing through the plates and generating steam. To remove this impurity, a scumming arrangement is applied, which is effective enough in its way, but wasteful. During the generation of steam, these impurities are ballooned to the surface of the water by the bubbles of steam, and can be blown out. But this blowing out is intermittent, and blows steam away as well as the dirt. In Belgium, what appears to be a useful appliance has been introduced, which has the two-fold advantage of being continuous, and instead of wasting the steam it comes in contact with the feed-water on its way to the boiler and imparts the heat to it. This apparatus is largely and successfully used on the Continent, and is now being adopted in some parts of this country. It is known as Dervaux's system, and is likely to be a good deal heard of in England.

Feed Valve and Steam Valve.

All that is necessary to say about these mountings is that the feed valve should be non-return—that is, while water can pass freely into the boiler none should be able to come back through the feed valve. Boilers will work better if the water is kept about one uniform level, and a careful attendant can manage this without any special contrivance. Assistance is rendered by having a fixed pointer showing the proper level in the gauge glass. Steam valves should allow easy passage of steam, so as not to diminish the pressure by friction and wire drawing. The steam pipe in the boiler communicating with the valve is placed high up in the boiler, and is perforated on the upper side. Steam can get in only at these perforations,

and thus dry steam is more likely to be obtained than if the pipe were open-ended or had the perforations on the under side. Formerly, it was a general practice to place in the steam pipes connecting the boilers an expansion joint between each two boilers and the same thing in the feed pipes. The joint used consisted of two flat circular plates connected to the pipes and joined together at the circumference, so as to allow a space between. These so-called expansion joints did much more harm than good. They answered well enough as contraction joints when the pressure of steam within the discs and the contracting metal acted in the same direction. But when the expanding metal and the pressure between the plates opposed each other, then "Greek met Greek," and there came the "tug of war." Suppose the pipes were 12 in. diameter and the expansion joint 3 ft. diameter and a pressure of 60 lb. per square inch of steam, there was a pressure of about 54,000 lb. assisting contraction and opposing expansion. An expansion joint should act equally well for contraction or expansion. In feed pipes no arrangement between the boilers need be made for expansion, and as regards steam pipes the steam receiver shown in figs. 166 and 167, with its separate springing pipe for each boiler, will, if mounted upon pillars provided with rollers, allow for any expansion or contraction that may be required. Expansion joints will have to be considered in dealing with pumping and with haulage, and sketches of defective and effective expansion arrangements will come more appropriately in those sections.

Furnace Mountings.

The furnace of a boiler comprises mouthpiece with doors and bedplate, firebars, bridge, and ashpit. In an externally-fired boiler the furnace is distinct from the boiler. Cast-iron mouthpieces are objectionable, because they are cumbersome, costly, and liable to fracture. The best are made of wrought iron, and placed within the circle of the rivets, so as to leave them exposed to view. Fronts of boilers have usually no protection to prevent radiation. This has been attempted by casing the front with brickwork, and is not a good plan—it harbours moisture and conceals defects. A better arrangement is

to have a coating of good non-conducting material applied in a frame which may be conveniently removed at any time. Fire doors should be provided with a sliding ventilating grid on the outside, and a perforated box baffle plate on the inside, the aggregate area of the air passages being about 3 square inches for each square foot of fire-grate. A good proportion of fire-grate for a Lancashire boiler about 30 ft. long is 6 ft. long by 2 ft. 9 in. wide; and the heating surface of such a boiler, fitted with Galloway tubes, will be 400 square feet in the external shell, 500 square feet in the internal flues, and 30 square feet in the water pipes—giving a total of 930 square feet, which ought to generate steam equal to 200 horse-power, and consume, in doing so, of average slack, 6 cwt. or 7 cwt. per hour. Many boilers have attached a kind of fender, which, placed in front of the boiler at the bottom, is supposed to keep the ashes away from the front plate. It is desirable that these ashes should be kept away, but it is a very general practice to allow the ashes to lie against the front plate for some considerable time after the fires have been cleaned. They lie there and water is thrown upon them to cool them, with the result that the bottoms of these front plates are very often nearly eaten away. These fenders referred to are scarcely the most effective means of preventing this, because moist ashes may unseen collect inside the fender, and if so the remedy is worse than the disease. The better and more effective plan is to prohibit the watering of ashes in such a position, and compel their removal with as little delay as possible. This line of action will be a more efficient remedy than fenders. [The writer is indebted to Mr. G. Caldwell, of Moss Hall Collieries, for sketch of an arrangement to prevent ashes lying against the boiler. This sketch will be given in Chapter XV.] Leaking gauge taps, allowing water to trickle down the boiler fronts, are also a cause of injury which a little inspection and rigour can prevent. Careful and regular tests should be made to ascertain that the water-gauge taps are not getting choked up.

All steam boilers should be covered. First of all, each separate boiler should be well coated on the top, that is, the part not enclosed by the seating, with a good non-

Fig. 170.—Corrugated Roof over Range of Boilers.

[To face page 129.]

Fig. 174.—Chimney Top.

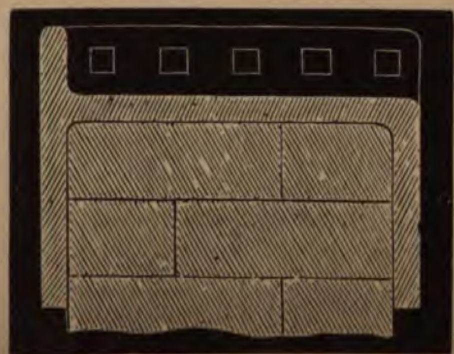


Fig. 171.—Parallel Chimney.

Fig. 172.—Battered Chimney.

Fig. 173.—Chimney with separate Casing Inside.

conducting substance not injurious to the plates. And on this composition should be placed a ring of brickwork. But this is not sufficient. The range of boilers and the fire-hole should be put under a house or shed. Too much care can hardly be exercised in keeping the boilers warm. We ought not to be content with casing a cylinder and covering steam pipes; we ought by every means to avoid cooling influences upon boilers, and thus keep the steam generated as warm as possible. True economy consists in adopting all measures, although incurring expense at first, to avoid waste afterwards.

Fig. 170 shows a neat corrugated roof, resting upon either side walls or pillars. There should be room in the boiler flues for getting in to clear out the dust, which in course of time would quite choke up the passages; and the chimney should allow an easy and convenient entrance at the bottom for the same purpose. Chimneys are usually constructed much larger at the bottom than at the top, but as the same gases have to leave the chimney that enter it, the correct course would seem to be to make it parallel internally. We may do this by making the thickness equal from bottom to top, or by allowing batter outside and keeping the inside parallel, or approximately, by having an inner chimney for some distance up. (See figs. 171, 172, and 173.) A good batter for a chimney is ¾ to 1 in. per yard, and a good substantial top without cornice may be made by bell-mouthing the top and putting a plain cast-iron trough on. (See fig. 174.)

A good many calculations have been made as to the height and area of chimneys. The following very easily-remembered rough and ready rule may be of some service, and at any rate is given for what it is worth. Local authorities have decided that no boiler chimney be less than 30 yards high. Let that be adopted as our height for one, two, or three boilers, and add five yards of height for each additional boiler. As to area, allow 10 square feet for each boiler, and the following results come out:—

No. of Boilers.	Height of Chimney in yards.	Diameter in feet and decimals.
1	30	3·6
2	30	5·1
3	30	6·2

No. of Boilers.	Height of Chimney in yards.	Diameter in feet and decimals.
4	35	7·2
5	40	8·0
6	45	8·8
7	50	9·5
8	55	10·1
9	60	10·7
10	65	11·3
11	70	11·8
12	75	12·4
13	80	12·9
14	85	13·4
15	90	13·8
16	95	14·3
17	100	14·7
18	105	15·1
19	110	15·6
20	115	16·0
21	120	16·4

We have supposed the boilers to be each 7 ft. diameter, the flue area of which, with two flues, each 2 ft. 9 in. diameter, is nearly 12 square feet.

Mr. Robert Wilson has published, as a kind of appendix to his book on Steam Boilers, a few chapters on Boiler and Factory Chimneys, which are very ably written, and deal exhaustively with the work and proportions of chimneys. Mr. Wilson's calculations are too advanced to be of much service to many practical men connected with collieries. To such the above simple rules may be of some service. Those who are more capable will do well to study the little work referred to.

It may be remarked that the inner chimney, which is built of firebricks, as shown in fig. 173, has proved effective in preventing cracks in the outer structure, even without the application of iron hoops. The heat has not only a greater distance to travel, but has to pass across the open space separating the inner and outer structures. The trough of cast iron round the top prevents the crumbling away that so often occurs with chimneys, whether of stone or brick at the top. The bell-mouthing at the top gives a neat appearance, and avoids the injurious top heaviness caused by massive and so-called handsome cornices. Of the three forms of chimneys, square ones look the worst and are the worst; they offer more surface

to the wind. Octagonal chimneys present the best appearance, but are more difficult to build. Round chimneys, taking into consideration utility and appearance, are to be preferred. A good foundation for chimneys—especially high ones—is an all-important matter, and a good broad base of blast furnace slag, as already mentioned in connection with engine houses and engine pillars, answers as well as anything. Several years ago the writer had to take up a goodly number of stone blocks, formerly used as railway sleepers, and used them as foundation for two chimneys, each about 60 yards high. Chimneys should not be built too rapidly, because the mortar in the joints may set unequally, and in spite of all the efforts of the workmen, the structure will get out of the perpendicular. For a good chimney anything over fifty yards in height a yard per day is fair progress.

Smoke Prevention.

Proprietors of works have for some years been much harassed by legislation and officious busybodies, who seem to think that we can have all the material advantages which a country enjoys from large ironworks, collieries, &c., without any inconveniences or unpleasantness, and too much has been made of the smoke nuisance. London has been so strong on the subject that serious proposals have been made to adopt appliances which would enable anthracite or smokeless coal to be used for all purposes. This is not the way to meet the difficulty. England—fortunately for herself—amongst the nations of the earth, possesses valuable and extensive seams of bituminous or smoke-producing coal, and is not rich enough to allow these seams to remain unworked. We are told by smoke abolitionists that smoke is waste, and that if smoke be prevented we shall save fuel. No doubt, wherever "Act of Parliament smoke" passes from our chimneys we are losing some fuel, but not nearly so much as in the majority of cases where nothing is visible from our chimney tops. To obtain the full effect of fuel and prevent smoke we require perfect combustion, and the products will be chiefly carbonic acid gas, and we may get very near this result and make some black smoke. But, on the other hand, we may send from our chimneys carbonic oxide and

make no smoke, and lose one-third the effect of all the coal consumed. It is because many people do not or will not understand this that so much is made of the smoke question. If it were simply preventing smoke no proprietor would hesitate a moment, but to lose one ton of coals in every three tons is a serious matter indeed. To prevent smoke and get full effect from fuel we require correct proportions of fuel and air and a sufficiently high temperature. Unless we have all these the smoke may disappear, but so will a large proportion of the efficiency of the fuel. Amongst the many appliances that have been introduced perhaps the endless chain of Juckes has proved most effective. Introduced some thirty or thirty-five years ago it was largely applied to externally-fired boilers and answered well. So much work could not be got out of a boiler as with hand-firing, but the steam generation was more regular, and the boiler itself received less injury, and it was found possible to use fuel of an inferior quality, so far as size was concerned. But as the Cornish and Lancashire boilers were introduced the application of Juckes's furnace became less easy. An attempt was made to overcome the difficulty by cutting a hole from the internal flues through the bottom of the boiler for the endless chain, but this system was barbarous and was adapting the boiler to the furnace, not the furnace to the boiler. Another arrangement was to place the furnace under the Lancashire boiler and fire it externally, allowing the heated gases to pass through and round the boiler afterwards. Then it was endeavoured to crowd the whole business into the small internal flues and this did not succeed. Perhaps as good an arrangement as any is adopted at Bestwood. The Juckes's furnaces are placed in front of the boilers and surrounded by a combustion chamber from which the heated gases pass into the boiler flues and take their usual course. No machinery has come into use which will get the same amount of work from a given number of boilers as hand-firing. It did seem at one time that the solution of the difficulty would be mechanical stokers, injecting fixed quantities of air and fuel in the form of dust, but the author of that process Mr. T. R. Crampton, has for a long time devoted himself almost entirely to puddling. For

hand-firing it is recommended not to overwork a boiler, to maintain a good thickness of fire, to throw on little at once and often, to admit air after firing, to avoid the use of the rake. Another plan is to adopt side firing, and throw the fuel first on one side and then on the other. To carry out these suggestions, simple as they may appear, we require a more intelligent and better informed class of firemen.

Mr. Thomas Morris, of the Dallam and Bewsey Forges, Warrington and Wigan, which produce as much iron (and smoke) as perhaps any ironworks in the kingdom, has placed at the writer's disposal his views on smoke prevention, as follow:—"I have often contended that if any saving of fuel can be exercised, however small, by preventing smoke, it should be done in the marine boiler, for steam being equal, every ton of coal that is put in the vessel more than is needed robs it of a cubic yard of space wherein cargo should be stowed. But my faith is poor in the economy of any principle that admits air anywhere between the back end of the grate and the uptake of the chimney. It should pass through or over the fire, or both at the same time; all schemes of letting air in at the bridge must of necessity let as much in at one time as another, unless worked automatically, or by hand, which would not be satisfactory long together. To ensure perfect combustion of the two heat-giving components, *i.e.*, the conversion of all the carbon into carbonic acid, and all the hydrogen into water, as the gas I am writing by is converted into, when burning steadily, is utterly impossible. Human skill never was, nor will it ever be, able to dole out the exact equivalent of air for each fresh charge of coals. If it were possible to always have coal of the same constituents, of the same size, mechanical appliances for feeding the grate, temperature and a dry atmosphere always the same, you would not be far from a smokeless chimney. Some of these things cannot be had. Cost of carriage compels us to use the bituminous coal that lies close to us; neither will keen competition allow anything but rigid economy, if you are to be successful in your business. The conclusions one has come to after reading and thinking over the numerous schemes for economising fuel, and preventing black smoke from

the furnaces of steam boilers, are these:—Have no inlets of air between the fire and the chimney. Get all the small holes you can in the baffle plate, and that as well in towards the fire as reason will allow. A mechanical stoker that will feed without admitting too much air. If you have not got this, insist on the stoker putting the damper down before opening the door to put coals on. If possible, make opening the door lower the damper, and *vice versa*; let your fuel be as equal in size as you can get it, the grate clean from dead ashes and well covered with fire, fire light and often, allowing no incandescence to be left without fresh fuel. Attend to these small things, and you will have no great cause to fear the smoke inspector."

Mr. Lavington Fletcher, of the Manchester Steam Users' Association, says that a Lancashire boiler about 27 or 28 feet long and 7 feet diameter will consume 15 to 20 tons of coal in 60 hours, representing from 17 to 23 pounds per square foot of firegrate per hour without distressing the boiler and without producing smoke. All that is needed being to maintain a good thickness of fire, throw on the coal a little and often, admit a little air above the bars for a short time after firing, and avoid the use of the rake. The coal may either be spread over the whole surface of the fire, or thrown at alternate firings, first to one side of the furnace and then to the other, on the side firing system. A Lancashire boiler experimented on at Wigan, with furnaces 2 ft. 7½ in. diameter and a firegrate 4 ft. long, evaporated 83·54 cubic feet of water per hour from a temperature of 100 degs. Fahr. at the rate of 10·44 pounds of water per pound of coal, when burning 24 pounds of coal per square foot of firegrate per hour. With a firegrate 6 ft. long it evaporated per hour 98·58 cubic feet of water at the rate of 10·37 pounds of water per pound of coal, and burnt 19 pounds of coal per square foot of firegrate per hour. These results were obtained at atmospheric pressure, with the help of a water heater, with good round coal and without making smoke. The experiments referred to above were made on the works of the Wigan Coal and Iron Company, for the Lancashire and Cheshire Coal Association, and produced results as given by Mr. Fletcher. They were experiments pure and simple, carried on under

Mr. Fletcher's personal superintendence, assisted by skilled subordinates. When boilers in actual use are superintended and worked by men of similar stamp we shall get better results, and our chimneys will vomit forth less black smoke.

The consumption of fuel at collieries for steam generation is in nearly all cases very large, scarcely ever being less than 5 per cent., and in some cases amounting to 10 per cent. of the output, and if such consumption could be saved a handsome profit would be at the disposal of the proprietor. Forges use the gases from their puddling furnaces, and blast furnaces do likewise with the gases which formerly escaped at the open tops. Collieries cannot always follow such a laudable example, but where coke is manufactured they may. In the North of England, where coke making is an important industry, advantage is taken of what would otherwise be waste heat, and a large amount of fuel thus saved. Instead of allowing the flues of the coke ovens to communicate direct to the chimney, they are connected to the boiler flues, and the gases generate all the steam required. The system is in operation at Barnsley, Hetton, Langley Park, Bear Park, and Burnley. And after some years' experience it can be said that the coke is not deteriorated in quality, the boilers wear longer, because the action of the heat and the generation of steam are more uniform, and fuel is saved. One colliery in 1882, with a total output of 1,000 tons per day, estimated the saving at £2,000 per year, and the temperature in the flue leading to the chimney after the heat had done its work at the boilers was 1,400 degs. Fahr., showing that a larger number of boilers could be worked from the same ovens. Even more than this is now being, not tried, but actually accomplished. At several Northern collieries by-products, in the form of ammoniacal liquor, are extracted from the gases, without lessening the percentage, or lowering the quality of the coke, and after this the gases are used for generating steam. This has been done at Pease's West for over a year.

CHAPTER XV.

STEAM BOILERS FOR SURFACE AND UNDERGROUND.

Boiler Explosions—Not so frequent as in former Years—Boilers work at Higher Pressure and are better made—Advantage of Inspection in preventing Accidents—Proposed Compulsory Inspection—Causes of Explosions—Defective Material—Tests should be made of the Plates—Bad Construction—Weak Joints—Distortion from Punching—Over-pressure—Sticking of Safety Valves—Cowburn's Dead-weight Safety Valve will not stick—Over-working—Too heavily fired—Plates get weakened by Over-heating—Injury from heated Gases passing along Top of Boilers—Explosion at Blackburn from that Cause—Explosion on the "Thunderer" from Safety Valve sticking—Leakage at Rivets and at Blow-off—Feed Pipes stopped—Deposit upon the Plates—Soft Deposit and Hard—Best Preventive—Good Water and frequent Cleaning—Cold Feed Water—Open-ended Pipe discharging downwards—How Feed Pipes inside the Boiler should be arranged—No Open End—No Discharge downwards—Internal and External Corrosion—Method of clearing away Ashes at Moss Hall Collieries—Wear and Tear—Cracks about Rivets—Grooving about Joints—Incompetent Firemen—John Windle and Ring Plates—Legislation—Hugh Mason's Act of Parliament—Strength of Boilers—Transverse and Longitudinal Strains—Rules for Strength of Boilers—Table of Strength, from 3 ft. to 7½ ft. diameter, and from one-eighth to one Inch Thick—Example to ascertain Strength of Lancashire Boiler—And of Cornish Boiler—R. Wilson on "Steam Boilers"—W. Morgans on "Criticisms on Stationary Steam Boilers."

It it proposed in this chapter to touch upon some of the causes which lead up to boiler explosions and to mention one or two means of ensuring safety. Boiler explosions are not nearly so frequent as in former years. It would seem that as the need of higher pressures has increased proprietors and users of boilers have recognised that disasters when they occur will be greater with high pressure than with low, and consequently have been more careful in allowing a sufficient margin for safety. A considerable amount of good has also been effected by the various insurance and inspection associations, which, for a fixed sum per year, make inspections and give advice. Some

very distinguished men would go so far as to make independent inspection compulsory, but although agreeing that some owners and users of boilers display great recklessness, the harassing effect of this over-legislation in matters which ought to be managed without Parliamentary interference inclines one to hope that Parliament will leave us alone as regards our boilers. At the same time boiler owners should remember that carelessness as regards boilers jeopardises the lives of their workpeople, and their position under the Employers' Liability Act should induce them to do all that is necessary.

1. The first cause of explosions is defective material, which is either deficient in ductility or deficient in tensile strength. It may safely be laid down as a rule that plates for boilers and all materials used in their construction should be equal to not less than 20 tons per square inch of tensile strength and 20 per cent. of ductility. It is not difficult to provide this in boiler specifications, and it can be ensured by having samples taken from each separate boiler plate and tested.

2. Explosions may result from bad construction. This may be through bad punching or riveting, or too many plates with weak joints wrongly arranged. Punching boiler plates distorts them and makes holes unshapely. By drilling we avoid injury to a plate, and can produce almost a perfect hole. The weak direction of the boiler, as has already been pointed out, is in the strain on the horizontal joints, any form of which is weaker than a solid plate. Diagonal joints have been tried, but until we can dispense with horizontal joints altogether perhaps the best plan is to have as few plates in each ring as possible, and the joints made double riveted and well broken. Machine riveting produces better results than are possible by hand. Hydraulic riveting has of late years come into very general use. Hand riveting is slow, expensive, unequal and injurious to rivets and to plates. Hydraulic riveting will do the work as quickly as rivets can be put in, the pressure is uniform, the action is a gradual squeeze (not a sudden blow) and no injury is done upon either rivets or plates. An objection has been made to machine riveting that a washer is liable to form between the plates. This ought not to be in any case, but is less

likely with the hydraulic arrangement than any other. A hydraulic riveter can be either fixed or portable, and in the latter case is so light as to be carried about easily; and another great convenience is that, unlike the steam riveter, it keeps cool and is not an inconvenience in the handling; altogether it may be said that machine riveting is the best, and hydraulic power is the best form of machine riveting.

3. Explosions are caused by over-pressure, which may arise from accident or from wilfulness. Where a boiler is clearly unfit for the pressure at which it works, the best thing is that it should explode as soon as possible, provided no one is injured except the guilty party. Over-pressure may be caused by an accident, such as the safety valve sticking. The means for preventing this have been laid down in Chapter XIV. Every boiler should be provided with at least one of the dead-weight safety valves on the Cowburn principle. These valves cannot stick, and the steam cannot rise above the fixed blowing-off pressure.

4. Explosions may happen through a boiler being overworked. Too much fuel is thrown upon the fire, the water within the boiler cannot receive the heat sufficiently quickly from the plates, which become red-hot, and are consequently so seriously weakened as to be unable to resist the working pressure. In some cases the heated gases are allowed to pass above the boiler on their way to the chimney. The two boilers that exploded at Blackburn worked in this way, and it was given in evidence that this arrangement might have caused the accident. The safer plan at any rate is to not allow the heated gases to act upon the boiler above the water level. It may be said that the plates must reach a temperature much higher than these gases before weakening begins. The fact remains that the parts of the boiler are not working under the same conditions, and this inevitably produces weakness. If more than the usual heating surface is required put in corrugated flues, which will give the surface and increase the strength.

5. Leakages occur at the rivets or at the blow-off arrangement and the boiler frees itself of water without the attendant noticing it. There is nothing left but steam

in a nearly red-hot boiler. It has been argued that such a condition of things will not bring about an explosion directly. Perhaps not, but it weakens the boiler, and an accident is more liable afterwards. A low-water safety valve, with an alarm to warn the attendant when his water from any cause is too low, is an efficient appliance. It is not necessary for there to be a leakage to produce an empty boiler. The feed pipes may be stopped, and a man may have turned his tap and think the feed is passing in when really not a drop is going. The low-water valve will open whenever the water gets too low, and sound an alarm. In Lancashire and Cornish boilers the water level falling too low is a serious matter. The crown of the flue is laid bare and the fire commits its ravages upon them. Even without a low-water valve if a boiler has two distinct water-gauge glasses a careful attendant will avoid such mishaps as this.

6. Deposit upon the plates, which may be very hard and adhere, or it may be quite soft and lie on the bottom. The hard scurf is not easily dealt with, and a little of it is not a serious injury; indeed, for marine boilers it is preferred that there should be a slight coating of this. Tallow and oil have been put into boilers each time after cleaning for the purpose of preventing this formation of scurf, but this practice is more than questionable. The tallow and dirt make their way into the cylinder and do more harm there than they do good to the boiler. It is far better to treat the water before it enters the boiler than afterwards, and when some scurf cannot be avoided the boiler should be cleaned frequently, and the coating inside well and carefully removed. The soft material, which simply represents matter which has been in mechanical combination with the water and which, if not blown away, will settle in considerable quantity, should either be kept out altogether by filtration or else removed by scumming while the boiler is at work. The ordinary scumming arrangements are wasteful, because they throw away a lot of steam, and ineffective because intermittent. We mentioned in Chapter XIV. Dervaux's system, whereby the action is continuous, and the heat of the steam expelling the impurities is not wasted, because it heats the feed-water entering the boiler.

7. Explosions may be caused by cold feed-water entering a boiler, especially if, as was common enough years ago, the feed was delivered through an open-ended pipe looking down. The result was the cold water kept the part of the boiler where it was delivered very cold, and as the other parts were hot, there was unequal expansion and contraction and plates would rip. However feed-water may be heated, whether by coming actually into contact with exhaust steam or not, whether it passes through a feed warmer or an injector, or an exhaust injector, matters nothing. But it is important for the safe working of any boiler that feed-water should be as high in temperature as possible, and should enter the boiler from the front along a pipe just below the water level, and whilst closed at the end should have holes in the top to allow the water to be discharged in the form of spray. It may appear almost superfluous to refer to the desirability of heating the feed-water, but the excuse for doing so must rest in its importance. A boiler works with infinitely more safety and regularity if fed with hot water. More steam can be generated with less fuel, and as a consequence fewer boilers will do the work. There is really nothing to prevent feed-water being heated to the boiling point corresponding with its particular pressure, and the advantages of turning water into a boiler full of hot water and steam at a temperature of 212 degs. or 220 degs., as compared with 50 degs. or 60 degs., is something substantial. The heater, as already described and sketched, heats feed-water to the boiling point. The ordinary Giffard's injector imparts considerable heat to the feed; and last of all, and best of all, we have now the exhaust injector, which not only feeds the boilers without using any fresh steam at all, but actually in doing so raises the temperature of the feed-water to something like 190 degs.

8. Internal or external corrosion will have a terrible effect even upon new strong boilers. The internal action can only be avoided by keeping out the injurious water, and to do this wholly, good water must be provided from some source, whilst to do it partially, the water before entering the boiler should be treated to remove as largely as possible the cause of injury. External corrosion is much more easily overcome, because it is caused chiefly by

FIG. 175.—SUBWAY FOR ASHES.

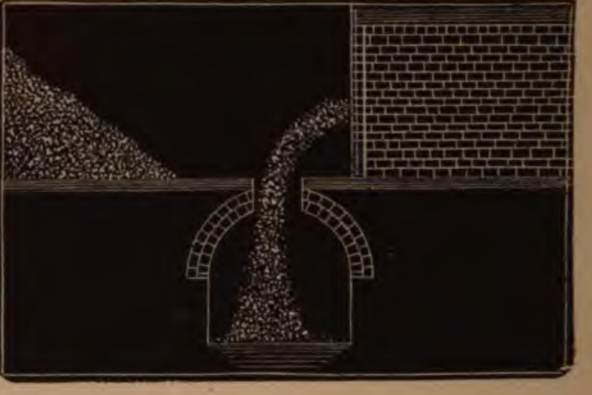


FIG. 176.—FRACTURES ABOUT RIVETS.

[To face page 141.]

water only, or water along with ashes being allowed to eat the plates away. A boiler can be so seated and covered that for a very long time no water will be able to make its way to the outer shell in such quantity as to prove injurious. And as regards wet ashes lying at the front, this can be prevented and should be prevented. Mr. G. Caldwell, of the Moss Hall Collieries, pointed out a very excellent method of dealing with ashes at their new colliery. There is an underground passage below the firing level containing their blow-off pipes, &c., and into which the ashes fall, so that they are not in contact with the boilers at all. (See fig. 175.) (See Appendix, Note O_1.)

9. But the most fruitful source of explosions is in the gradual and continuous wear and tear that goes on, and being gradual is liable to escape attention. Cracks occur, as in fig. 176, or grooving goes on, as shown in fig. 177, and this sort of thing, if allowed to go too far, will give trouble. The remedy for this is careful and frequent inspection. A good practice at collieries, unless the water is very good, is to clean and examine the boiler internally each month, and to give the boiler an entire examination, inside and out, flues and mountings and seating, once in each year. We owe undoubtedly in a large measure the lessened number of boiler explosions to the systematic inspections which now so generally prevail.

10, and last. Explosions are caused by incompetent firemen. No engine, however perfect, is capable of much work in the hands of a man who has no control over it; and no boiler, however well made, will do justice to its maker or owner or be really safe in charge of firemen who have little or no knowledge what a boiler is or what it does. Many explosions have been caused, not by bad material or workmanship or water, but by what is equal to all these defects combined—namely, a bad fireman. This is a defect which ought not to exist, because so easy to remedy. But unfortunately we nearly all seem to have drifted into the belief, at any rate we act up to it, that any man, or even lad, who can handle a spade, is qualified to look after a boiler.

We shall conclude this chapter by some remarks and rules and tables as to strength of boilers, and before doing so will revert for a moment to the question of endless

plates. Mr. John Windle, of Newton Heath, near Manchester, who has already been mentioned in these chapters with regard to the manufacture of endless plates for boilers, has, at the writer's request, submitted some drawings which cannot well be produced here, and some information which may be interesting to some readers. These endless plates can be made either of steel or iron, and almost any diameter, to a width of 4 ft. 6 in. A sample of plate and a ring were shown as made in this way, and nothing need excel the excellence of their manufacture. Dispensing with horizontal seams and introducing endless plates means increasing the strength of boilers or other wrought-iron cylindrical structures one-third, and in these days of increasing pressures this is an important matter. And then with regard to the cost, Mr. Windle, who speaks as no mere theorist on this matter, but as a thoroughly practical man, states that as the result of actual experience in making these plates he is satisfied they can be produced at as small a cost as the ordinary plates. What more can be desired? All authorities agree that endless plates will be a great improvement, and here it is proved that there will be no increased cost in the production. The writer ventures to express the earnest hope that at some future time he may have the pleasure of writing as to the successful establishment of an unquestionable, practical improvement in boiler construction.

Legislation.

While these articles are passing through the press no less an assembly than the House of Commons has been dealing with the subject of boilers. A Lancashire Member, Mr. Hugh Mason, a prominent member of the Executive of the Manchester Steam Users' Association, has introduced and has succeeded in passing through both Houses of Parliament, even in the comparatively barren session of 1882, what will probably prove a useful Act of Parliament. Many boiler owners have been alarmed lest Parliament, in its paternal inclinations should do with boilers as has already been done with mining and other industries, viz., practically take the management into its own hands, without taking the responsibility, and this was

FIG. 177.—GROOVING OF PLATES.

FIG. 179.—LONGITUDINAL STRAINS ON BOILERS EGG-ENDED.

FIG. 178.—TRANSVERSE STRAINS ON BOILERS EGG-ENDED.

FIG. 181.—LONGITUDINAL STRAINS ON BOILERS INTERNALLY FIRED.

FIG. 180.—TRANSVERSE STRAINS ON BOILERS INTERNALLY FIRED.

[To face page 143.]

not a thing to be desired. But the cardinal principle of this Act would seem to be that the Board of Trade should take an active position when enquiries are held as to the causes of boiler explosions. There cannot be much objection to interference of this character. Righteous owners and managers will have nothing to fear from investigation, and on the other hand, guilty parties will have a chance of being made responsible for their misdeeds. (See Appendix, Note O_2.)

Strength of Boilers.

Figs. 178, 179, 180, and 181 show the direction of strains to which externally and internally fired boilers are exposed. Taking the externally-fired boiler first, we find the pressures acting in the direction of the length amount to the area of the circle represented in fig. 178, showing cross-section of boiler multiplied by pressure in pounds per square inch; and the material of resistance is afforded by the circumference of the boiler multiplied by the thickness of plates. The pressures acting in the direction of the diameter amount to the area of fig. 179, showing longitudinal section of boiler multiplied by pressure in pounds per square inch. The material of resistance is afforded by the length of the boundary of fig. 179 multiplied by the thickness of plates.

Considered in this way we will take an example to find the pressures in the boiler in both these directions, the boiler being 6 ft. diameter and 40 ft. long, and the pressure 100 lb. per square inch. Also the strength of resistance with plates ½ in. thick and double-riveted joints. A circle of 6 ft. diameter has 4,071·5 square inches area × 100 = 407,150·0 lb. total pressure acting lengthwise. To find the area exposed to transverse pressure we must add a rectangle measuring 34ft. × 6ft. = 204 × 144 = 29,376 square inches area to 4,071·5 = 33,447·5 square inches area × 100 = 3,344,750·0 lb. pressure acting transversely. To resist the pressure acting lengthwise we have the circumference 226·0 × 0·5 = 113 square inches area of iron × 15 tons = 1,695 tons × 2,240 = 3,796,800 lb. resistance, as against 407,150 lb. pressure, being nearly ten times in favour of resistance. To resist the pressure acting crosswise we have the metal bounding the figure, namely,

circumference of two ends = 226 in. added to twice 408 = 816 + 226 = a total length of 1,042 × ·5 = 521 square inches area × 15 tons = 7,875 tons × 2,240 lb. of resistance to meet 3,344,750·0 lb. pressure, being about five times in favour of the resistance, showing that an ordinary externally-fired cylindrical boiler is twice as strong to resist pressures acting lengthwise as it is to resist pressures acting crosswise. In calculating the strength of Cornish boilers or Lancashire we proceed exactly the same to ascertain what we may call the diametrical pressure and the resistance opposed to it. But for pressure acting lengthwise we deduct the area of the flues, and in calculating the resistance we add the circumference of the flues by the thickness. So that in this case we increase the resistance and lessen the area of pressure. The ends of Cornish and Lancashire boilers are weak through being flat, but this can be remedied by gusset and longitudinal stays. And this being done, the only pressures we need consider in calculating the strength of a boiler are those acting transversely. For this reason we want the strongest form of joint we can possibly get for the horizontal seams, and would dispense with them altogether if possible, and failing that have them double riveted.

For useful information as to the strength of boilers no better work can be recommended than the little book on "Strength of materials," by Anderson, of which the writer has repeatedly had to express his indebtedness. Everybody should read this thoroughly reliable and practical book.

Rules as to Boilers.

(1.) No material for plates, rivets, or stays should be used having less tensile strength than 20 tons per square inch. (2.) Single riveted joints lessen the strength of plates nearly one-half, whilst double-riveted joints only weaken them about one-fourth, therefore, all seams exposed to most pressure, such as the horizontal seams, should be double riveted. The ring seams may be single riveted. (3.) To find the bursting strength of a cylindrical boiler, whether externally or internally fired, multiply twice the thickness of plates in inches by 15 tons, and bring it into pounds. This divided by the diameter in

inches will give the bursting pressure in pounds per square inch. (4.) To find what diameter a boiler whose thickness is given must be to burst with a certain pressure, multiply twice the thickness of plates in inches by 15 tons, and bring it into pounds; divide this by the pressure in pounds, and the result will give the diameter of boiler in inches. (5.) To find the bursting pressure of an externally-fired boiler, regarding only the pressure acting lengthwise, find the amount of iron in square inches area in the circumference of the boiler, and multiply by 15 tons and bring into pounds; then divide this by the area in square inches of the cross section of the boiler, and the result is bursting pressure in pounds per square inch. (6.) To find the bursting pressure of a Lancashire boiler, regarding only the pressures acting lengthwise, find the amount of square inches area of iron in circumference of shell of boiler and circumference of both flues, and multiply total by 15 tons and bring it into pounds; divide this by area of cross-section of boiler minus area of both flues; the result is bursting pressure in pounds per square inch. (7.) The margin of safety—that is, the bursting pressure—is sometimes as much as six times the working pressure, but in no case should be less than four.

The table which follows gives approximately the working pressure for all sizes of boilers, from 3 ft. to $7\frac{1}{2}$ ft. diameter, and for all thicknesses, from $\frac{1}{8}$ in. to 1 in.

EXAMPLE.

A Lancashire boiler measures 7 ft. 6 in. diameter, and has two flues, each measuring 34 in. diameter, and the whole shell and flues are made of $\frac{9}{16}$ plates, all the seams being double riveted. Find what pressure, acting lengthwise, will burst it. The bursting strength with double riveted joints may be taken as 15 tons per square inch. 7 ft. 6 in. diameter = 6361·75 square in. area. Two flues each, 34 in. diameter = 1815·75 square in. area. Therefore, area exposed to pressure = 6361·75 − 1815·75 = 4546·0 square inches. 7 ft. 6 in. diameter = 282·75 circumference. Two flues 34 in. diameter = 213·75 in. circumference. Therefore total area of resistance = 282·75 + 213·75 = 496·50 × $\frac{9}{16}$ = 279·25 square in. Strength per square inch = 15 tons = 33,600 lb., × 292·25 = 9,819,600·0 lb.

APPROXIMATE TABLE OF STRENGTHS.

Safe working strength of boilers with plates having tensile strength twenty tons per square inch, allowing one-fourth weakening by riveted joints.

Thickness of plates.	Diameter and Approximate Pressure in Pounds per Square Inch.									
Inch.	3 ft.	$3\frac{1}{2}$ ft.	4 ft.	$4\frac{1}{2}$ ft.	5 ft.	$5\frac{1}{2}$ ft.	6 ft.	$6\frac{1}{2}$ ft.	7 ft.	$7\frac{1}{2}$ ft.
$\frac{1}{8}$	58	50	44	39	35	32	29	27	25	23
$\frac{3}{16}$	87	75	66	58	52	48	43	40	37	34
$\frac{1}{4}$	116	100	88	78	70	64	58	54	50	46
$\frac{5}{16}$	145	125	110	97	87	80	72	67	62	57
$\frac{3}{8}$	174	150	132	117	105	96	87	81	75	69
$\frac{7}{16}$	203	175	154	136	122	112	101	94	87	80
$\frac{1}{2}$	232	200	176	156	140	128	116	108	100	92
$\frac{9}{16}$	261	225	198	175	157	144	130	121	112	103
$\frac{5}{8}$	290	250	220	195	175	160	145	135	125	115
$\frac{11}{16}$	319	275	242	214	192	176	159	148	137	126
$\frac{3}{4}$	348	300	264	234	210	192	174	162	150	138
$\frac{13}{16}$	377	325	286	253	227	208	188	175	162	149
$\frac{7}{8}$	406	350	308	273	245	224	203	189	175	161
$\frac{15}{16}$	435	375	330	292	262	240	217	202	187	172
1	464	400	352	312	280	256	232	216	200	184

The margin of safety allowed is four, therefore approximate bursting pressure is four times the above.

total strength of resistance. The area of pressure is 4,546 square inch. Therefore 9,819,600 ÷ 4,546 = 2,160 lb. per square inch, the pressure required to burst this boiler acting lengthwise.

EXAMPLE.

A Cornish boiler measures 6 ft. diameter, and is made of plates half-inch thick in the shell and in the flue, which is 40 in. diameter. The circular seams are single riveted. Find what pressure, acting lengthwise, will burst it. The bursting strength with single-riveted joints we will assum 10 tons per square in. 6 ft. diameter = 4,071·5 square in. area; 40 in. diameter = 1,256·5 square in. area. Therefore, area exposed to pressure = 4,071·5 − 1,256·5 = 2,815·0 square in. 6 ft. circumference = 226 in. — 40 in. circumference 125·5 in. Therefore total area of resistance = 226 + 125·5 = 351·5 × ½ = 175·75 square in. Strength per square in. = 10 tons = 22,400 lb. × 175·75 = 3,936,800·0 lb. total strength of resistance. The area of pressure is 2,815 square in. Therefore 3,936,800 ÷ 2,815 = 1,398 lb. per square inch, the pressure required to burst this boiler acting lengthwise.

The remarkable difference in the strain lengthwise compared with crosswise will be seen by comparing the results just obtained with the actual working strengths of boilers 7 ft. 6 in. and 6 ft. diameter and $\frac{9}{16}$ in. and ½ in. thick respectively, as given in the table. And this makes the argument tell all the more strongly in favour of endless plates. Boilers should have no horizontal seams.

To those of his readers who care to study the subject of boilers more in detail and with more advantage, the writer recommends to their notice two excellent little books, viz., by R. Wilson, a "Treatise on Steam Boilers," and by W. Morgans, "Criticisms on Stationary Steam Boilers."

CHAPTER XVI.

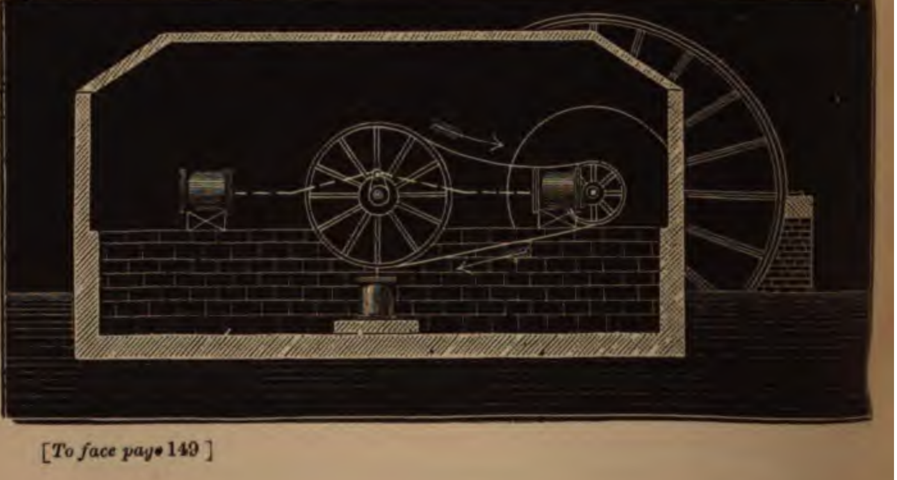
MECHANICAL VENTILATION.

Disputable Points—Best Information in the *Transactions* of various Institutes of Engineers—Fan with Iron Casing and Iron Chimney and Circular Iron Drift—Fan with two Engines and Rope Gearing—Advantages of Rope Gearing—Lighting of Mines—George Stephenson—Ventilation is now a branch of Mechanical Engineering—Furnace Ventilation not condemned—Mechanical Ventilators have had an Uphill Fight—Nicholas Wood—William Fairbairn—Recent Enlargement of Fans and Improvements in Machinery for Driving—Fans now can deal with any Quantity of Air—Furnace the most Economical for deep Mines—Fan the most Economical for Shallower Mines—Atkinson on Fan and Furnace Ventilation—Guibal on Fan and Furnace Ventilation—Advantages of the Fan should not be exaggerated—Probable Depth at which Fan and Furnace will be equal in point of Economy—Special Advantages of the Fan—Upcast Shaft and the Ropes and Rods receive less Injury—Winding in Upcast Shafts less Inconvenient—Banking is less Impeded—Surrounding Country less Injured—Mechanical Ventilator produces a more Regular Current than a Furnace—Pumps placed in Upcast Shaft—Danger from Fire with Furnace—Accident with Winding Rope in Upcast—Balance Rope scarcely workable in Furnace Shaft—Arguments against the Fan—More liable to get out of Order—The Current soon stops when the Fan ceases Work—Every Fan should have a spare Engine which can be coupled in a few Minutes—Nicholas Wood on Ventilating Machines—Smeaton—Brunton—Gurney—Nixon—Struvé—William Fairbairn on Ventilation—Nicholas Wood's opinion that no Mechanical Power was capable of producing 250,000 cubic feet of Air per Minute.

It is not intended in this and the next few chapters on mechanical ventilation to bring under consideration a lot of sensational and striking information simply because it is new. So far as matters with which our ablest engineers have dealt and have left still to some extent in doubt, the writer will not presume to step in and decide. But there is plenty of scope for dealing with principles and facts that have been established and are generally accepted. Information of this kind is plentifully scattered up and down the *Transactions* of the various institutes of engineers, and some good will be done to the general reader by bringing such information into a compact form. One's own

FIG. 182.—FAN WITH IRON CASING.

FIG. 183.—FAN DRIVEN WITH ROPE GEARING.



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views on questionable points must occasionally be expressed, but this will be done modestly, always bearing in mind the principal aim of the publication, not to air the individual views of the writer, but to put together useful information, obtained from the best sources and taken from the highest authorities. Fig. 182 accompanying this chapter represents a ventilating machine with iron casing and circular iron drift, shown from the drift side. Fig. 183 gives the same arrangement from the engine-house side, and shows two horizontal engines, either one of which connects with the ventilator. To enable a slow-working engine to produce a high speed pulleys are introduced, connected by rope gearing. With a system of this kind the driving machinery will be noiseless in its working, and the speed of the ventilator will depend only on the proportion of the pulleys. The ventilating and lighting of mines have always occupied, and deservedly so, much attention from colliery engineers, and just at present, perhaps, more than at any former period. Although one of the very best safety lamps ever introduced, namely, the "Geordie," was invented by almost the father of the mechanical engineering profession, so far as collieries are concerned, the lighting of mines scarcely comes within the scope of mechanical engineering, and at any rate will not be dealt with here. Such a subject must be left to those who possess the needful practical experience, combined with the special scientific knowledge to deal with it exhaustively. Ventilation is now as much a part of mechanical engineering as winding or pumping or hauling, but it must not be understood that because mechanical ventilation only is dealt with that therefore furnace ventilation is necessarily condemned. It is only when machinery is brought into use that ventilation becomes a mechanical subject, and these chapters deal with none other. It is proposed to state a few special advantages obtained by machinery, leaving the advocates of the furnace to defend their own cause. Afterwards, the construction and principles of the chief machines brought at all extensively into use during the last thirty or forty years will have to be described. And, lastly, the appliances whereby mechanical ventilators obtain their power, including engines with and without condensing arrangements, engines coupled to the machine

direct, and those which do the work by means of straps or ropes.

Mechanical ventilators have had rather an uphill fight. It is not many years since such eminent authorities in the engineering world as Mr. Nicholas Wood and Sir William Fairbairn, men whom we were all proud of when living, and whose memories we cherish now that they are dead, declared that no machine could pass through a mine any such quantity of air as 250,000 cubic feet per minute. Had those intellectual giants lived a few years longer they would have seen even greater results than that achieved. Wood and Fairbairn only expressed an opinion in their day which perhaps even the inventors of some of the machines would hardly have disputed. Mechanical ventilators, the best of them, have surpassed the expectations of those who introduced them. And this, as it is hoped will be shown further on, is owing, not so much to improvement in the principle of the ventilator itself, because Guibal, for instance, is, to all intents and purposes, what it was a quarter of a century ago; but to increase in size and advancement in the moving mechanism. Formerly a machine 30 ft. in diameter was considered large; now we have them 50 ft. In the early days any engine was good enough, but now it is rightly considered that a ventilating machine is incomplete and imperfect unless it has a high-class engine attached. The general opinion arrived at now is that machines can be constructed to deal with practically any quantity of air, certainly any quantity that can be obtained by other means, and that as to economy in the consumption of fuel the furnace has the advantage for very deep mines, and the machine has the advantage for mines which are not so deep. What the exact depth is at which the two systems become about equal has not been satisfactorily determined, and probably never will, because it would depend not only on the different circumstances of different mines but also on the varying conditions of any one mine.

Mr. Atkinson, late Government inspector of mines for the Durham coalfield, who was the foremost man of his time as a contributor to mining literature, has given his opinion, based upon many years' experience, as follows:— Assuming that the sources of loss are the same in each

case, that is, that the loss of fuel in a furnace from the cooling in the upcast shaft is equivalent to the power expended in overcoming the resistances in a ventilating machine; also assuming that the ventilating machine utilises 60 per cent. of the engine power, and that it requires a consumption of 8 lb. of coal for each indicated horse-power per hour of the engine, he estimates that with an average temperature in the upcast shaft of 100 degs. Fahr., the depth at which machine and furnace are equal in efficiency would be 960 yards; with an average upcast temperature of 150 degs. Fahr. the depth would be 1,040 yards, and with an average upcast temperature 200 degs. Fahr. the depth would be 1,130 yards. Then with a higher consumption of coal per indicated horse-power per hour the results would come out differently. Taking the same average temperatures of the upcast shaft, viz,, 100, 150, and 200 degs. Fahr., the depths would be for 10 lb. of coal, 760, 830, and 900 yards, whilst for 12 lb. of coal the depths would be 640, 700, and 750 yards, showing practically that as the consumption of coal increased the depth at which the two systems became uniform decreased. But if we follow this calculation up, and instead of taking an outrageously high consumption, such as either 8 or 10 or 12 lb. per indicated horse-power per hour, we take a reasonable expenditure of fuel, what do we arrive at then?

In a previous chapter a winding engine (the winding engine at Monkwearmouth, Chapter VI.), so old as almost to deserve the title antiquated, was described, and the consumption of coal given as 6 lb. per indicated horse-power per hour; and this for intermittent work. We expect and obtain much better results from continuous work. So long ago as 1872 experiments were made in Liverpool with a very large number of marine engines (see Mr. F. J. Bramwell's paper and Dr. Siemens' presidential address in the *Transactions* of Mechanical Engineers for 1872) and it was shown that the average consumption of coal did not exceed 2 lb. per indicated horse-power per hour. Marine engines have no advantages which engines driving mechanical ventilators may not possess, and surely what was accomplished with marine engines ten years ago ought to be possible with

engines for mechanical ventilators now. And with engines working so economically how would Mr. Atkinson's figures come out? The mechanical ventilator would excel the furnace even in point of economy at any depth, whatever the upcast shaft temperature. There is nothing unreasonable in expecting a horse-power from 2 lb. of coal per hour. Indeed, Mr. E. A. Cowper, ex-president of the Institution of Mechanical Engineers, has done this with 1½ lb. of coal. The very best engines, either compound or otherwise, can be applied, and almost a perfect vacuum should be obtainable, because the work is regular and continuous, and the engine can work at any speed by the use of gearing, or can be applied direct. None of the objections peculiar to winding engines apply here.

M. Guibal, another very eminent authority on mining matters, who has made ventilation the study of his life, and has earned a well-deserved success, made some calculations. He said that if a furnace in a 12 ft. shaft, 400 yards deep, circulated 53,000 cubic feet of air per minute, against a total resistance represented by 3·3 in. of water gauge, with an average excess of temperature of 108 degs. Fahr. in the upcast shaft above the downcast, and had a consumption of coals equal 31 lb. per horse-power per hour in the air, estimated upon the total resistance—then a mechanical ventilator utilising 60 per cent. of the power employed would, under the same conditions, consume 11 lb. of coal per horse-power per hour in the air, being a saving of 64 per cent. At a depth of 550 yards, and circulating the same volume of air, the consumption of the furnace would be 22 lb. of coal, and that of the mechanical ventilator 11 lb., showing a saving of 50 per cent. And following up these calculations as we did with Mr. Atkinson's, and assuming an engine working as an engine should do, and can do, with 2 lb. of coal per indicated horse-power per hour, what do we find? In the first case a saving, not of 64 per cent., but of over 90 per cent., and in the second case, not of merely 50 per cent., but of nearly 90 per cent. Mr. Atkinson's and M. Guibal's figures prove a little too much; the mechanical ventilator is scarcely so efficient compared with the furnace economically as they put it, and most eminent engineers of experience agree that beyond 500 or 600 yards in depth

the furnace is the more economical. There is no need for, and no benefit to be derived from exaggerating the economical efficiency of the mechanical ventilators, more especially as they possess other striking advantages apart even from economy. The upcast shaft is not injured by the products from the furnace, the winding ropes and conductors and pump arrangement are free from the injurious influence, winding is not only always possible, but convenient; whereas with a furnace the shaft being always highly heated and often full of smoke, makes winding under such circumstances disagreeable. Work at the bank is impeded, and the surrounding country injured by the fumes from the furnace. Even the general practice of placing a chimney of some height at the upcast, although to a large extent it removes obnoxious products from the pit banks, and scatters them over a larger area, does not lessen their injurious influence. With a mechanical ventilator this is all avoided, and instead of an irregular current produced by a dangerous fire placed underground and badly supervised, the mechanical ventilator is upon the surface, can be worked to a nicety, and is easy of supervision.

It may be said that pump appliances should be placed in the downcast—perhaps so; but at collieries we have to deal with many things, not as they should be, but as they are. It will occur to those unfortunate subjects of Her Majesty honoured with diplomas of the Home Office that if they could have colliery affairs exactly as they wished their positions would be less onerous to themselves and more profitable to their employers. A little while ago the wood-work, such as pump-rods, horsetrees, &c., in a heated upcast shaft got on fire, and did considerable damage. Some years ago a winding rope had been standing for some time in a highly heated upcast shaft, and the cage at the bottom. It was then coiled upon the drum and left there for several hours, the cage being brought to bank. When the cage had to be let down again the rope was found to have contracted and broken; the cage went down the pit. Still another circumstance; at a colliery with cylindrical drum and round ropes, the depth being considerable, the tail-rope was applied to the bottom of the cages to balance the

load, and good working results were obtained. But unfortunately it was an upcast shaft, and when the rope was coiled upon the drum it cooled down, and the weight of the balance rope preventing the winding rope drawing itself in, the wood lags of the drum broke. The balance rope had to be dispensed with. These are actual results to show what, for the matter of that, is clear enough without—that a furnace shaft for winding causes inconvenience, amounting, in some cases, to danger. With mechanical ventilation there is no heated upcast, no damage to shaft, no injury to ropes, rods, and horsetrees, no smoke impeding winding and banking, and no products doing damage to surrounding lands. With a furnace there is also always some danger of fire, and in a great many cases there have been fires underground caused by the furnace, with more or less disastrous results. No better or safer or more regular or even more economical method of ventilation need be desired than with a machine placed at the surface, and deriving its power from the same boilers as the winding and pumping and hauling engines. A strong argument for the furnace as against the fan is made on other grounds than those of economy—namely, that it cannot get out of order unexpectedly, and that the ventilation will be kept up for a long time after feeding the furnace has ceased, whereas any machinery is liable to get out of order, and immediately the machine stops, so does the ventilation. This is true to a very large extent, although it is not a fact that ventilation is suspended immediately the machine ceases to work. It is no use disputing the fact that all the persons in a mine would have to be withdrawn as soon as possible if a machine broke down. Mishaps have occurred, although rarely, and they have always been with the engine, not the machine itself—in which the chances are really a million to one against getting out of order. In every case there should be a duplicate engine, which could be substituted at the week end, and at a well-regulated colliery, in case of emergency, the engine can be changed in a few minutes, indeed, so quickly that no harm can result.

The following extracts are from speeches made by Mr. Nicholas Wood and Mr. William Fairbairn, at the

Newcastle-upon-Tyne meeting, and printed in the *Transactions* of Institution of Mechanical Engineers, August, 1858, page 202. Mr. Wood said:—"No improvements in principle have been made in the mode of ventilating the coalmines of Northumberland and Durham within the last fifty years. The furnace has been the standard method adopted in these two counties from the earliest periods of coalmining, and it is substantially the standard mode of ventilation employed almost universally at the present time. Attempts have been made to introduce other methods of producing currents in mines, but the furnace is still considered the most efficient ventilating power. Producing ventilation by pumping the air out of the mine was practised in Smeaton's time. Mr. Brunton proposed the centrifugal ventilating machine. More recently the steam jet of Mr. Gurney was brought prominently before the coalowners, even by legislative recommendation, and still more recently the more perfect and to a certain extent more effective machines of Mr. Nasmyth and Mr. Struvé. Still, the furnace is the predominant power." Page 233, Mr. Wood says:—"Fans worked well, and were very serviceable for special application, where it was necessary to resort to some temporary means of ventilation from the top until the pit was cleared, but the case was a very different one when such enormous quantities of air had to be dealt with as 250,000 cubic feet per minute, and he did not see the practicability of any mechanical ventilation exceeding that performance." Page 234, Mr. William Fairbairn said:—"As to the mode of ventilation, he felt satisfied that so large a quantity of air as a current of 250,000 cubic feet per minute could not be accomplished by mechanical means, whether of a fan or a pump, and that the only resource was the furnace ventilation where very large quantities had to be supplied."—Paper on "Newcastle Colliery Working," read by Mr. Nicholas Wood, Mr. W. G. Armstrong in the chair.

CHAPTER XVII.

MECHANICAL VENTILATION.

Compression or Exhaustion for Ventilation—How a Current in a Mine is produced—The Furnace—Expansion of Air with Increased Temperature—How to Determine the Ventilating Pressure with a Furnace—Absolute Temperature—Fahrenheit Temperature—Absolute Steam Pressure—Ordinary Steam Pressure—How Machines produce a Current—Ventilation by Compression—Comparison between Compression and Exhaustion—Advantages on the side of Compression—Advantages on the side of Exhaustion—Exhausting Arrangements most Popular—Means of Ventilation in case Machine breaks down—Steam Pipe at bottom of Upcast—Action of Steam Jet—Machines need not break down—Suggestion for two Fans alongside—Blowing Engines for Blast Furnaces—Quantity of Air limited—Pressure very high—Therefore Blowing Engines answer best—But in Mines the Quantity of Air is very large and Pressure low—Therefore Exhausting Fans are best—Ventilating Machines on Blowing Principles have been tried and failed—Special Difficulties—Great Dimensions—Low Speed—Great Friction—Covering in a Fan Pit when used only for Ventilation—When used for Winding—Various Arrangements for allowing Loading and Unloading of Cages without inward Leakage—Sliding Doors and False Bottoms to Cages—Doors on Hinges—Chambers surrounding Headgear—W. Cochrane in the *Transactions* of Mechanical Engineers for 1869—Lectures on Mining by Callon—W. Galloway—Le Neve Foster.

To produce a current in the mine, whether by furnace or machine, we have to make the two columns in the upcast and downcast of different densities. Either we must make the column in the upcast lighter, causing it to ascend, and in forming a partial vacuum cause the heavier column in the downcast to follow it, or we must make the column in the downcast heavier, and so force the upcast column up. The furnace adopts the former method and lightens the upcast column by heat, causing it to expand. And the useful effect of the furnace, and conditions necessary for its most perfect action are readily deduced from a consideration of the effects of the expansion of air by heat. When the pressure remains the same, the volume of air is expanded by each degree of rise in temperature $\frac{1}{460}$th part of its corresponding volume at the temperature of zero

Fahrenheit. So that the length of a column of air of the same sectional area in the heated upcast is increased in the proportion of 460 + temperature of upcast shaft to 460 + temperature of downcast shaft. The difference between the weights of these two columns of air having the same total height forms the ventilating pressure. And as the velocity of a current of air is proportionate to the square root of the pressure producing it, the velocity of the current, and consequently the volume of air circulating through passages of given area and length is proportionate to the square root of the difference between the temperatures of the upcast and downcast shafts when the depth of the upcast remains constant, or is proportionate to the square root of this when the difference of temperature between the upcast and downcast remains constant. Students are often troubled as to the distinction between this absolute temperature and the ordinary Fahrenheit temperature. A word here may be in season. It has been proved that heat exists very much below the Fahrenheit zero, and it is accepted that the real zero would be found at 460 deg. below the ordinary zero. To distinguish the one from the other we speak of absolute zero and ordinary zero. And knowing an ordinary temperature, say of 60 deg. Fahr., it is easy to convert this into terms of absolute temperature by adding 460 and making it 520 deg. absolute. We find the same kind of thing in dealing with steam pressures. Our ordinary pressures reckon from the atmosphere, which itself has a pressure of 15 lb. or thereabouts. To convert the ordinary pressures into absolute pressures we add 15. This becomes important when dealing with expansion, because, suppose we have 45 lb. ordinary pressure at the commencement of the stroke and cut off at one-third, thus expanding three times, it does not mean that we shall have 15 lb. ordinary pressure at the end. We add 15 to 45, making 60, and take one-third of 60 = 20 lb. absolute, being 5 lb. ordinary pressure. The generality of machines follow the same lines, and lighten the upcast column by extracting air from it. But ventilation may be made effective by forcing air into the downcast by arrangements after the manner of blowing engines at blast furnaces. The question arises, which is best? and at least one gentleman had decided

the question some years ago, who coolly argued that by compressing air all friction vanished, and there was simply the weight of air to deal with. If this were so exhausting machines would disappear, but, unfortunately, we shall have friction to deal with whether we adopt compression or exhaustion.

In comparing the two systems of placing the compressing machinery at the top of the downcast or the exhausting machinery at the top of the upcast, in the first place there will be less bulk of air to deal with by the former method, therefore the exhausting machine will require a little more power than the compressing machine in the ratio of the square of the pressure of the air compressed by the latter to the square of the pressure of the air expanded by the former.

Another point to consider is that ventilating machines act by producing a general state of either compression or exhaustion in the interior of a mine, so that according to the nature of the machine the pressure at any given point in the workings is either greater or less than it would be if the air were at rest. The blowing machine increases the pressure at the point in question, the exhausting machine diminishes it; the blowing machine tends to hinder the outflow of firedamp, the latter on the contrary favours it. This matters little for any given condition of ventilation, but when the condition is changed it may become a matter of some importance. A sudden fall of atmospheric pressure, such as that which takes place in stormy weather, tends to produce in some mines an outflow of gas, and it is necessary to compensate for this by increased ventilation. When the barometer falls, the increased ventilation means a greater degree of compression in the one case and a greater degree of rarefaction in the other; it tends to correct the influence of the barometric depression in the case of a compressing machine, and to augment it in that of an exhausting machine. So that in the second place, as in the first, the advantages would seem clearly to be on the side of compression.

In the third place, if the ventilation comes to a sudden standstill, owing to some accident to the ventilating machine, then the first effect of the return to rest is to restore the pressure at each point to that of repose. There

is therefore a reduction of pressure in the case of the compressing machine—that is to say, the equivalent of a sudden fall of the barometer in the first case and of a rise in the second. Here we have an advantage on the side of the exhausting machine.

In the fourth case comes the point as to which shaft we can most conveniently close, the downcast or the upcast. If we only use one shaft for winding, the difficulty vanishes, because we can absolutely close over the top of the ventilating shaft, either downcast or upcast as the case may be. But if both shafts are to be used for winding, some contrivance has to be introduced to allow loading and unloading of the cages without leakage. Practically, the same appliance would do in either case, but it does seem less likely to avoid a rush of air out from a compressing machine than a rush of air into an exhausting machine. There do seem some decided advantages in favour of both arrangements, and the ventilating machine most generally adopted is one which could be applied in either way, either for exhaustion or compression. But better results are obtained with it as an exhauster than a compressor, and this, together with the fact that leakage can more effectively be avoided, has no doubt led to the general adoption of the exhausting principle in ventilation.

Several proposals have been made for the continuation of the ventilation in the event of the machine unexpectedly stopping through break-down, and the simplest method would seem to be in having a pipe in the upcast shaft descending to the bottom, by means of which steam from the boilers can be sent down to the point at which the return air enters the shaft. The steam jet produced in this way heats the return air and produces an effect similar to that of a furnace. This can be continued by firing the boilers until the ventilating machine has been repaired and set to work again. But really there is no reason why properly constructed machines should break down; they should be constructed to avoid this.

Break-downs may be caused by the engine, but if there is, as there should be in all cases, another engine, the defect can be remedied in a few minutes—that is, before any evil result can arise. Sometimes crank pins have

broken, and where both engines connect to one pin this is awkward; and shafts have broken. But neither of these accidents ought to occur, and both can be provided against.

But admitting to the fullest extent the possibility of an engine or machine getting out of order unexpectedly and stopping, any evil results could be effectually guarded against by having two machines placed side by side, each having its own engine, so that in case anything happens to one the other can immediately be started. The objection in this case of course is the expense, and the risk of break-down with a well designed and well constructed machine is so slight that really it scarcely seems justifiable to incur the expense.

In connection with ventilation it has sometimes been urged that blowing engines are effective for blast furnaces. So they are. And why not have blowing engines for collieries? The circumstances are not similar. A ventilating machine has to displace a much larger quantity of air, and this displacement requires much feebler compression or expansion measured by the height of the water gauge. In blowing engines for blast furnaces the object is to compress a limited mass of air under a sufficiently great pressure to assure a high velocity in the tuyeres. In a mine, on the other hand, we desire simply to displace a large volume of air without going at a higher velocity than that which is necessary in order to make it pass through a passage of a given section. A blowing engine for blast furnaces in which coke is used supplies not more than 10,000 cubic feet of air per minute, and the pressure of this blast will reach perhaps half-a-dozen pounds per square inch, equal 14 or 15 ft. of water gauge. Whereas some mines require nearly a quarter of a million of cubic feet of air per minute, and the depression, which is dependent only on the resistance which the air meets with, will not exceed a few inches of water gauge. The ventilating machines of a mine, compared with the blowing engine at blast furnaces, may have to displace twenty or thirty times more air with a depression fifty or sixty times smaller.

Ventilating machines of the blowing engine type are now antiquated. The employment of pistons and valves presents serious difficulties, and is very disadvantageous as

Fig. 184.—Fan Pit used for Ventilation only.

Fig. 185.—Fan Pit used for Winding, Doors at Top.

[To face page 161.]

regards the motive power required. The difficulties lie principally in the great dimensions which the cylinders require to have, so great that the pistons cannot be driven except at a very low speed, and the unfavourable results are due to two causes. The feeble depression may become equal to that which is required to open and keep open the exhausting or the discharging valves, and there is an important loss of power in the friction of the piston on the internal surface of the cylinders. Wherever a ventilating machine is at work some means must be adopted of covering over the upcast shaft, so as to assure that no air shall reach the machine except what passes through the mine. If the shaft is used only for ventilation there is no difficulty, and it may be bricked up and covered over simply with planks, as shown in fig. 184, which in case of explosion would be lifted off and probably prevent worse results. But when the shaft is a winding shaft it is not so easy, and a good many plans have been adopted with more or less success. Provision has to be made so that the cage can reach and leave the surface, and that the rush of air in shall be as slight as possible during this operation. Some inward leakage is unavoidable, because the rope must work through any cover provided, and as winding ropes must have freedom slight inward leakage cannot be helped. The simplest plan is where a cover of wood or iron simply drops over the opening in the pit bank through which the cages have to pass. This cover is made to fit tightly, so that there is no escape when the cover is down, and when the cage is up that is supposed to fill up the opening. The only advantage of this arrangement is its simplicity, but it is not effective—it cannot be, because even if the cage accurately fitted the opening it has to be drawn above in course of decking, and when this is so there is nothing to prevent the air rushing in. Another arrangement is shown in fig. 185 in which the headgear is enclosed all round and on the top, except a space for the winding ropes. A door is provided at the level of the pit bank, which falls of itself as the cage leaves the bank and is raised by the cage reaching the surface. This arrangement is also defective, because if the cage is drawn, as it must necessarily be sometimes, above the bank level, there is a wide opening left for the

air to rush in. This defect has been overcome by placing troughs below the level of the pit bank and suspending additional bottoms to cages. These bottoms act as pistons, the troughs being considered as cylinders, and can be arranged to allow the cage to rise some distance above pit bank without letting the air rush in. These troughs and extra bottoms are also shown in fig. 185. Still another arrangement, which is simple and efficient enough, but requires considerable distance between level of fan drift and level of pit bank. Two sets of doors are fixed and arranged somewhat after the manner of gates at railway crossings, but instead of the opening of one pair opening the other also, in this case the opening of one pair closes the other, and the closing of one pair opens the other. The idea is to have always closed doors between the drift and the pit bank. When the cage leaves the surface it opens the lower doors and the upper ones close. When the cage is coming to the surface it opens the upper doors and closes the lower. (See fig. 186.) It might be said that there is danger of the wrong doors being closed and the cage striking them—say a descending cage be held there for a time, and afterwards as the weight accumulated drop, and perhaps break the rope. Such a condition of things is most improbable, and could easily be made impossible. The arrangement proposed when ventilating machines were first introduced into England seems to some extent as simple and efficient as any. (See fig. 187.) A chamber is made on each side of the headgear, with doors at the headgear and doors outside, as in a fan drift entrance. Either the outer or inner doors are always closed. When the chamber is being charged with empty tubs, or with materials to go down the pit, or with men, the outer doors are open and the inner doors closed. When the cage is being unloaded or loaded, the inner doors are open and the outer doors closed. And to enable the engineman, or at any rate some one on the pit bank to see the action of the cage and what was going on in the interior, the needful glass could be inserted.

In the preparation of this and following chapters the writer has studied with pleasure, and received material benefit from Mr. Cochrane's paper on mine ventilation in

FIG. 186.—FAN PIT USED FOR WINDING, DOORS IN SHAFT.

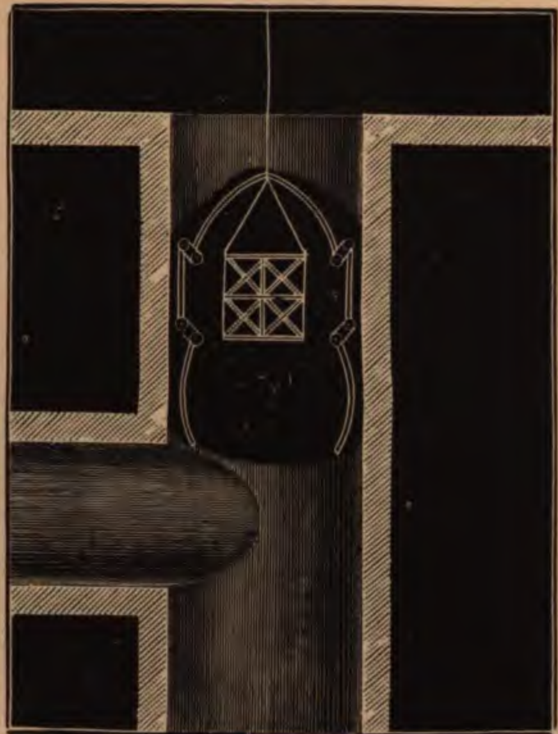
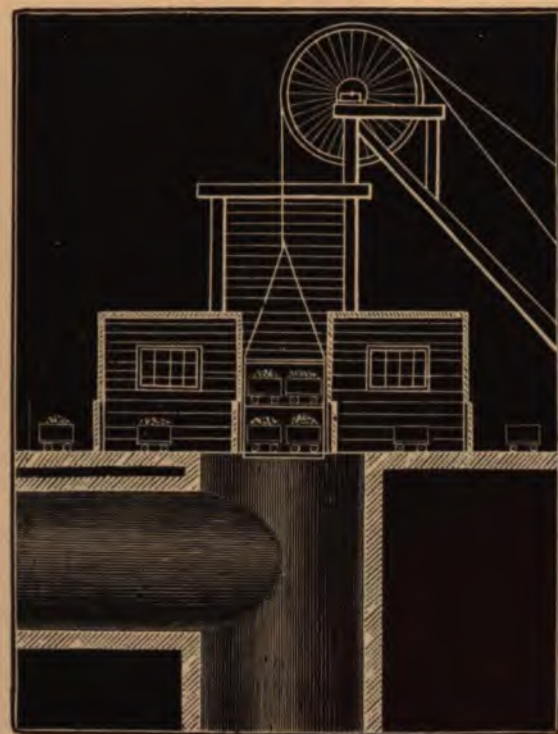


FIG. 187.—FAN PIT USED FOR WINDING, CHAMBER ROUND HEADGEAR.



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the *Transactions* of Mechanical Engineers and lectures on mining delivered at the School of Mines, in Paris, by M. Callon, Inspector General of Mines, and ably translated into English at the author's request by Mr. Galloway, mining engineer, and Dr. Le Neve Foster, H.M. Inspector of Mines. This excellent translation should be read by all mining students. All the conclusions arrived at will not commend themselves to English readers as absolutely correct, but the work contains a lot of useful, practical, well illustrated information not to be found in any English book, and in matters appertaining to mechanical ventilation, foreigners do more than command respect—they deserve it.

At the Bestwood Collieries a very elaborate arrangement has been made for winding at a fan pit. There is a cylinder of wrought iron as large in diameter as the pit and carried nearly to the top of the headgear. On two opposite sides of this vertical cylinder there are two branch tubes nearly as large, and also of wrought iron. These tubes take the place of the chambers referred to in fig. 187. To enable a cage to be taken off or put on, one of these branch tubes rests upon wheels, and can be separated from the vertical cylinder and wheeled away. The arrangement is said to answer well, although probably equal results were obtainable at much less expense. But the inconvenience even with the best appliances, and in some cases the serious delay in loading and unloading has induced proprietors at many of the best modern collieries to have shafts used for nothing but ventilation. There can be no doubt the winding will be more expeditious and the possible output greater if there be none of these doors and kindred appliances in connection with ventilating machines. And there can also be no doubt the ventilation will be better and a fan show a higher useful effect if attached to a shaft not used for winding. In all new collieries fan shafts should not be used for winding or pumping.

CHAPTER XVIII.

MECHANICAL VENTILATION.

Various kinds of Ventilating Machines—Those which act like Pumps—Those which sweep out a definite Volume of Air each Revolution—Fans acting on the Centrifugal Principle—Ventilating by Machinery very ancient—Old German Miners—Power of Falling Water—Heat and Momentum of Steam—Catalan process of Iron Manufacture—Principle of Falling Water producing a Current—Injury to Ventilation by having Pumps in Upcast Shafts—How Falling Water is used in Hilly Mining Districts—The Archimedean or Dutch Screw—The Hydro-pneumatic Screw of Guibal—Ventilation by Steam Jet not economical—Best form of Steam Jet—Good Results with Dry Shafts—Bad Results with Wet Shafts—Principle of the Blast in Locomotives—Dr. Siemens' Steam Jet—For Pneumatic Dispatch Tubes—For Gas Producers—Giffard's Injector—The Ejector Condenser—The Exhaust Steam Injector truvé's Machine—Nixon's Machine merely a Horizontal Arrangement of the Struvé—Defects of this Principle of Ventilator—Report of North of England Committee on the Struvé—Fabry—But little known in England—Lemielle—Large Machine—Low Velocity—Small Useful Effect—Popular at one time in France and Belgium—Cooke—Experiments at Upleatham, Lofthouse and Hutton—W. Daniel in *Transactions* of Mechanical Engineers—Root—Experiments at Chilton—E. H. Carbutt in *Transactions* of Mechanical Engineers—Fabry, Lemielle, Struvé and Nixon lack Simplicity, and cannot be relied upon for Efficiency—Cooke and Root also lack the Simplicity of the Centrifugal Ventilator.

It is proposed in this and following chapters to say something as to the principle and construction of the ventilating machines that have been at all extensively used; for convenience we may divide them into three classes—first, those which act like pumps, and are provided with pistons and valves, as in the Struvé and the Nixon; second, those which sweep out a definite volume of air each revolution, such as Lemielle, Fabry, Cook and Root; third, fans acting on the centrifugal principle, as illustrated in Nasmyth, Biram, Brunton, Rammell, Waddell, Schiele, and Guibal.

It might just be remarked, as showing how history seems to repeat itself in matters of this kind as of everything else, and that virtually "there is nothing new under the sun"—that during a discussion at Birmingham in

1856 it was stated that there was nothing new in the principle of ventilation by purely mechanical means, the same principle having been in use centuries ago on the Continent, although of comparatively recent introduction into this country. The old German miners had used an inverted tub placed in water, and worked up and down by a lever, with an air-valve at the top opening inwards, the fresh air being alternately drawn into the tub, and expelled along an air main conducting it into the working. Probably the lack of success attending early efforts in connection with mechanical ventilation was because there was nothing like the same necessity as in our time, mining operations being not only much more limited in their scope, but in proportion to their extent, the danger materially less.

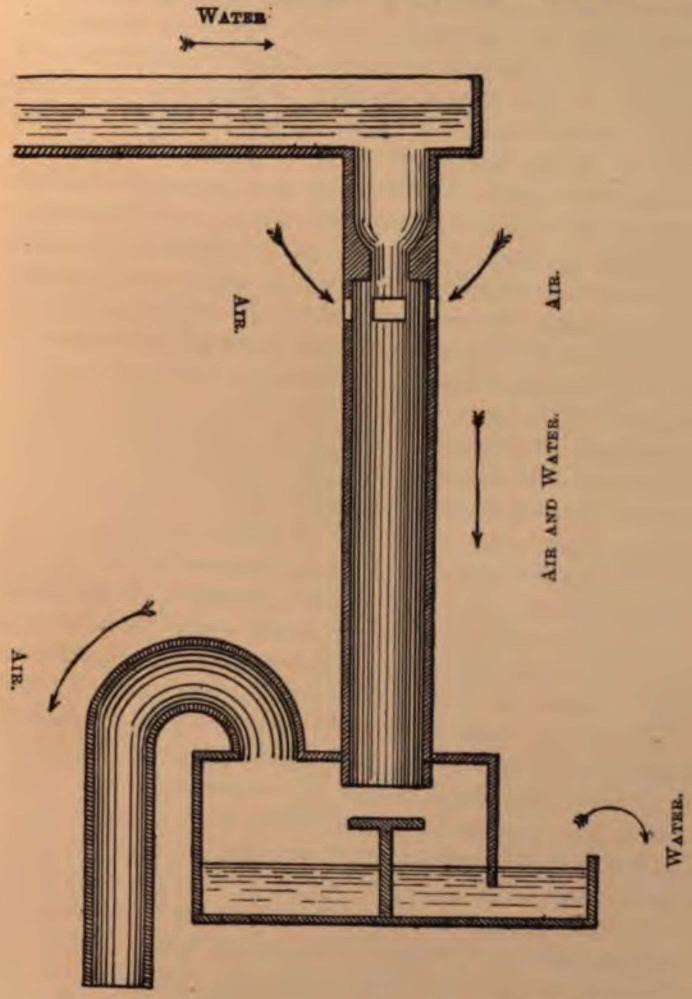
But there are other methods of effecting ventilation, either without mechanism or else such as are not included in the three classes named; and these we will deal with first, and it will be well to refer to efforts made in such directions as utilising the power of falling water, or the heat and momentum of steam, for producing a current without the intervention of machines.

An air current has been produced by the employment of a waterfall, and this arrangement is not unlike that extensively used in the early manufacture of iron by what was known as the Catalan process, and might be termed a water-blast apparatus. The action was based upon the fact that falling water drags the surrounding and entangled air along with it, producing an exhausting effect when the air can only enter by certain properly arranged orifices. The apparatus consisted of a vertical pipe slightly contracted just below its upper end, at which the water is admitted, and provided with small openings or aspirators immediately below the contraction, through which the air is drawn in and carried away by the current of water. The arrangement produced a low useful effect. We may, however, assume that falling water will produce a current in the same direction that it falls; and although such falling water may not have a high useful effect, we should learn a useful lesson, and be careful not to have pumps or to wind water, if it can be avoided, in upcast shafts, because water more or less will be falling down the shaft

and opposing the current; whereas, placed in the downcast, should water find its way down the pit from the teeming trough or the pump stocks, the tendency will be to help the current. Before passing away from this part of the subject it may be said that at one time the application of water power to produce a ventilating current was popular in some mining districts. Where a head of water can be obtained on a hill-side, and there is a level or adit to conduct the water away after having performed its duty in falling from a sufficient height, it may produce a low useful effect, but it costs nothing, therefore is economical. Fig. 188 gives a sufficiently clear idea how the air and the water pass together down a vertical pipe, and, falling upon a kind of dashboard at the bottom, separate. The water falls and passes away to the right, whilst the air liberated by the shock rises, and making its way to the left passes round the curved pipes and produces a current.

An appliance was tried a considerable time ago which involved the action of a screw revolving in water, and was called the Archimedean or Dutch screw, placed horizontally in a cylinder and filled with water to such a height that the lower edge of the shaft which carries the screw is always immersed to a certain extent. By this contrivance the compartments which are formed above the water by the spires of the helicoidal surface and the upper half of the cylinder are isolated from each other, and a rotary movement transmitted to the screw produces a motion of translation along the axis of the mass of air which fills these compartments. The air is drawn in at one end of the screw and forced out at the other. This arrangement was called the hydro-pneumatic screw, and was suggested by M. Guibal, who afterwards worked on much more successful lines. It affords another example of efforts tending towards a certain result being first directed in scarcely the right groove, but leading up to a successful issue. The arrangement was not successful, chiefly because the friction of the screw was so enormous in proportion to the work done. This was certain to be, because the screw, whether constructed for moving air or for moving coals, as sometimes used at collieries, generates too much friction to produce high useful effect.

FIG. 188.—AIR CURRENT FROM FALLING WATER.



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The direct employment of steam without the intervention of machinery has been tried to produce ventilation, and certainly was a more feasible arrangement than falling water or Archimedean screws. Because steam will have somewhat the same influence as a furnace; it will heat the air, and in so doing rarefy it, causing a partial vacuum. The advantage of such a system is that the furnace underground is not needed, and the steam can be conveyed simply in a pipe from the range of surface boilers. In the matter of simplicity it is all right, but unless the heat applied to steam is to be used for actual pressure it is expensive heat. And in this case we lose, so far as ventilation is concerned, such heat as passes up the boiler chimney, but which in furnace ventilation passes up the pit shaft and heats the air. And however much economy we may effect by using steam in a well-constructed steam engine with high expansion and good condenser, we can hardly expect to get good results from simply turning steam into a shaft to heat the air, and if the steam condenses, as it is liable to do, the products of condensation being water, would in falling tend to reverse the current. In effecting ventilation by steam jet, sometimes a pipe is simply carried some distance down the shaft and allowed to deliver its contents, without any special contrivance, at the end. At other times the arrangement is more elaborate and comprises a down pipe supplying a circle pipe fitted to something like the sweep of the shaft. This circle pipe is perforated with small holes on the higher side, and allows the steam to issue in a number of small jets. By this means the steam comes immediately in contact with a very much larger air surface and is proportionately more effective. If the shaft is a very dry one, some good will be done, but if the shaft is wet, immediately the steam comes in contact with the wet sides, condensation will ensue, and instead of the steam assisting the air to ascend, the water resulting from condensation will fall and impede the current. The principle of using the steam jet as a means of ventilation is that it acts upon air surrounding it and administers to it its momentum. Taken in this way, steam under certain circumstances and favourable conditions may give fair results and has shown good work in several ways. The draught of the locomo-

tive, without which the locomotive would be a very imperfect machine, is obtained by the action of a jet of steam administering momentum to the air in the smoke box, and by so doing producing a draught through the tubes.

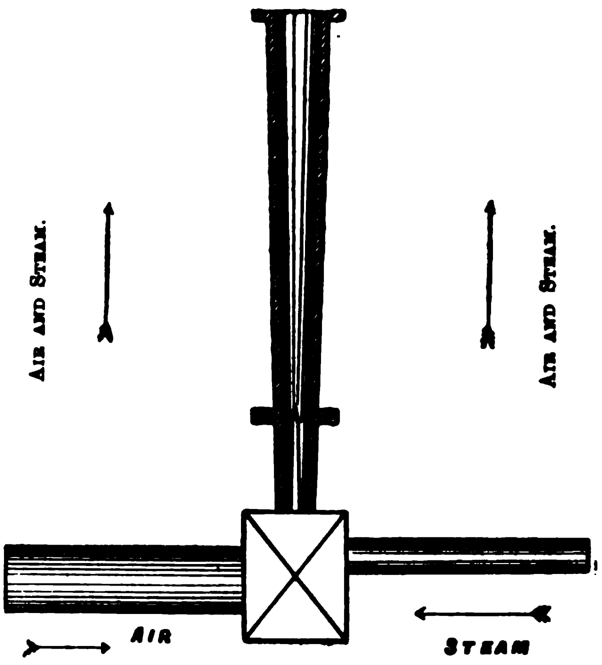
Dr. Siemens has constructed a steam jet exhausting apparatus, producing a vacuum of 12 lb. per square inch, with steam at 30 lb. above the atmosphere, and has obtained as high a useful effect as in the ordinary steam engine. His appliance was such that a thin annular jet of steam was produced, and this steam acts upon the air inside and outside; and when the steam and air had fairly united, the passage through which the combined mass passes is an expanding parabolic delivery funnel, in which the velocity is gradually reduced, and the momentum of the steam utilised in propelling the air (see fig. 189).

Dr. Siemens was successful in applying the steam jet to the working of pneumatic despatch tubes, in which, having a length of four miles, a vacuum of 5 lb. per square inch was obtained from a steam pressure of 40 lb., and an average speed through a 3 in. tube attained of fourteen miles an hour; and also as blowers for his gas producers. But, after all, passing air through a 3 in. tube is very different from dealing with it in a pit shaft 18 ft. or 20 ft. diameter, and having to deal with hundreds of thousands of cubic feet per minute; and it is not likely that steam jets will ever compete with good machines for effective and economical ventilation. Still, the principles which guided Dr. Siemens in his successful experiments are worth noting:—

1. By gradually contracting the area of the air passages on approaching the jet the velocity of motion of the entering air is so much accelerated before it is brought in contact with the steam that the difference in the velocity of the two currents at the point where they come together is much reduced, and in consequence the eddies which previously impaired the efficiency of the steam jet, are to a great extent obviated, and a higher useful result is realised.

2. By the annular form of the steam jet the extent of surface contact between the air and steam is greatly increased, and the quantity of air delivered is by this

FIG. 189.—AIR CURRENT FROM STEAM JET.



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means very much augmented in proportion to the quantity of steam employed. Also the great extent of surface contact tends to diminish eddies.

3. By discharging the combined current of steam and air through the expanding parabolic delivery funnel of considerable length, in which its velocity is gradually reduced and its momentum accordingly utilised by being converted into pressure, the degree of exhaustion or compression produced by the steam jet is very materially increased under otherwise similar circumstances. And Dr. Siemens from his very elaborate and successful experiments arrived at the following conclusions:—(1.) The quantity of air delivered per minute by a steam jet depends upon the extent of surface contact between the air and the steam. (2.) The maximum degree of vacuum increases in direct proportion to the steam pressure. (3.) The quantity of air delivered per minute is in inverse relation to the weight of air acted upon. (4.) That the limits of air pressure attainable with a given pressure of steam are the same for compression or exhaustion.

Although mine ventilation by steam jet can scarcely be pronounced a success, there is really no wonder that efforts have been made to utilise the power of steam in this direction. Dr. Siemens' results, as just referred to, are sufficiently remarkable, and the locomotive blast is also strikingly valuable. But we have much more to go upon even than these. Giffard's injector, introduced into England some twenty-five years ago, took our engineering world by storm. Not only practical men but authorities on matters of science scoffed at the idea that water could be forced into a boiler by the direct contact of steam, not only not higher in pressure but even considerably lower. But there it was, working, in spite of all arguments to the contrary, and now thousands are in operation; and M. Giffard, who has so lately passed away from us, has left behind him the name and memory of a most successful inventor. Shortly after this, the principle was applied to purposes of condensation without air-pumps, and although the success as compared with the injector has been limited, still the inventor proved that by the action of a jet of exhaust steam he could utilise its momentum and obtain a vacuum.

And lastly, we have what is likely to prove a greater success than either—namely, the exhaust injector. This has already just been named, and at no distant date will demand special description. Here let it suffice to say that an exhaust injector fed with exhaust steam will force, by direct contact, water into a boiler working at a good pressure. No one could be more startled than the writer to have it proved in his presence by actual result that not only will this exhaust injector, working with exhaust, overcome steam at a good pressure, but that working with exhaust at 5 lb. below atmospheric pressure, it forced water into a boiler at 60 lb.

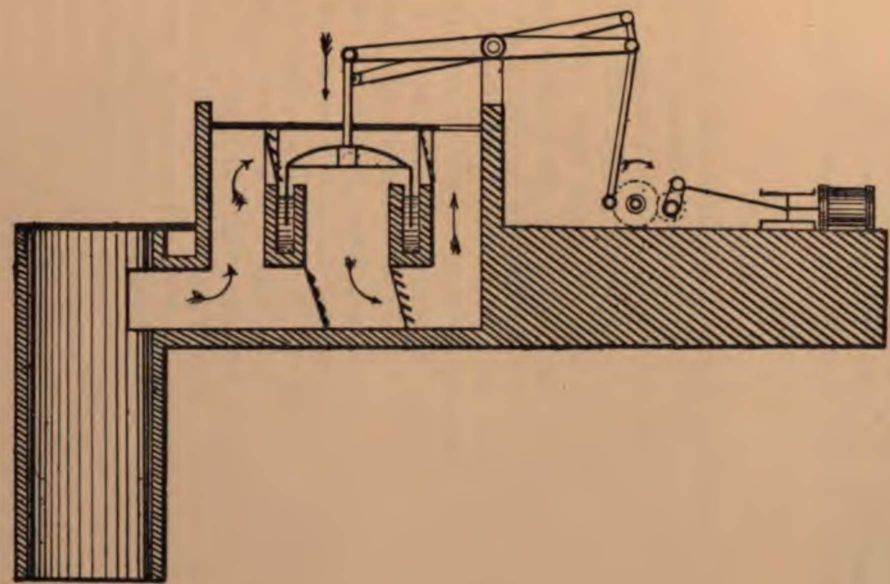
So much for the attempts in the past to obtain a ventilating current by water or steam in direct contact with the air to be moved. Those who wish to study the subject further will find abundant material of good quality in the first volume of *Transactions* of the North of England Institute of Mining Engineers—papers having been read by Mr. J. A. Longridge, in October, 1852, and by Mr. Nicholas Wood in December of the same year, and in February, 1853, all bearing upon the same subject. And whilst Dr. Siemens was president of the Mechanical Engineers he read a paper to that body in 1872.

We have now to deal with machinery applied in one form or another. It is not easy to determine the exact order in which ventilating machines were applied; but dividing them into classes we will endeavour to make some approach to the chronological order of those in each class, commencing with those that act as pumps.

Struve.

(See fig. 190.) The air is drawn from the mine by means of a pair of large aerometers made of boiler plates, and similar in construction to ordinary gasholders, each working up and down in a circular chamber of brickwork, the bottom edge of the aerometer being immersed in an annular trough of water in the walls of the chamber. At the top and bottom of each chamber are two sets of air-valves, consisting of simple wooden flaps hung upon vertical gratings which open inwards on the side communicating with the pit and

FIG. 190.—STRUVE VENTILATOR.



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outwards on the opposite side. In the up-stroke of the aerometer the air from the pit is drawn in along the passage and enters below the aerometer through the bottom inlet valves, while that above the aerometer is expelled through the top outlet valves. In the down stroke the air below the aerometer is expelled through the bottom outlet valves, while more air from the pit is drawn in above the aerometer through the top inlet valves. The two aerometers are worked by cranks at right angles to each other, thus rendering the draught of air from the pit practically uniform.

Nixon.

No sketch of this ventilator is necessary, because it is practically a horizontal application of the Struvé principle, by having a pair of pistons supported by wheels working upon rails. This arrangement was applied at Nixon's Navigation Pit, near Aberdare; but whereas in the vertical arrangement the water joint can be used, this is not so in the horizontal, and therefore Nixon's is hardly an improvement upon Struvé. Even the best adaptation of this principle is not to be recommended. Whether vertical or horizontal, these enormous pistons or aerometers have to be reversed twice each revolution, making high speed impossible, and generating considerable friction; and in the event of an explosion these would not be found suitable appliances. If the piston or pistons were coming towards the pit just at the moment of the explosion, the shock and the machinery would meet and would produce disastrous consequences. Even if the pistons were travelling from the pit the force of the explosion would probably accelerate their motion too much and do serious injury. Also the flap valves must be very numerous to give sufficient area of inlet and outlet opening for the air, and must afford opportunities for leakage and be costly to maintain. At a moderate speed and with valves in good order fair results have been obtained, but such appliances will not afford sufficient speed, will not deal with large enough quantities of air, and are liable to get out of order. If the number in use may be taken as showing the comparative efficiency, this class falls far behind, and we have very few indeed of

Struvé ventilators in England. It is only fair to state that the North of England Committee, in their very elaborate experiments, place the Struvé ventilator highest on the list as regards useful effect. Does anyone really believe that the Struvé is the best, even as regards useful effect? Does it not rather tend to show that the present method of comparing efficiencies of ventilators is misleading?

The second class embraces those which sweep out a definite volume of air each revolution, and includes amongst others the Fabry.

Fabry.

(See fig. 191.) This machine consists in reality of two wheels of equal diameter and each provided with three epicycloidal teeth, two of which are always in contact. The teeth are so arranged that they meet regularly—that is to say, during one entire revolution of the wheels two of the teeth are always in contact either on one side or the other of the line which joins their centres. The revolving wheels will produce an exhausting or blowing action, according to which direction they turn. The exhausting or blowing action takes place in a rectangular chamber which communicates with the workings to be ventilated. The dimensions of this chamber are determined by the distance between the centres of the two wheels on the one hand and by their width on the other. The teeth are merely simply epicycloidal surfaces which come into juxtaposition without exercising any pressure upon each other. The shafts which bear these two wheels are connected together by two ordinary toothed wheels having the same circumference. The three teeth of each wheel of the ventilator have an arc of 60 deg. each for their base upon the circumference. Their epicycloidal portions are connected to a blade projecting beyond their circumference and moving in a circular part of the envelope which commences at the lowest point of the wheel and embraces an arc of 120 degs.

In the early days of mechanical ventilation the Fabry ventilator was prominent on the Continent, but the writer is not aware that it ever obtained a foothold in this country.

Fig. 191.—Fabry Ventilator.

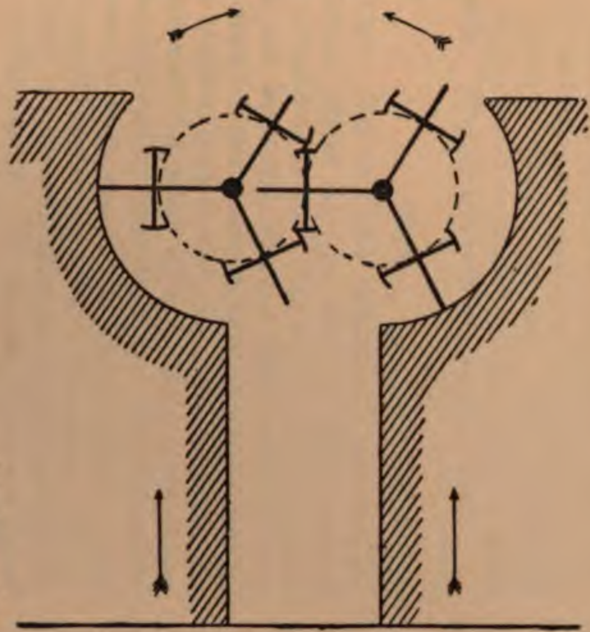
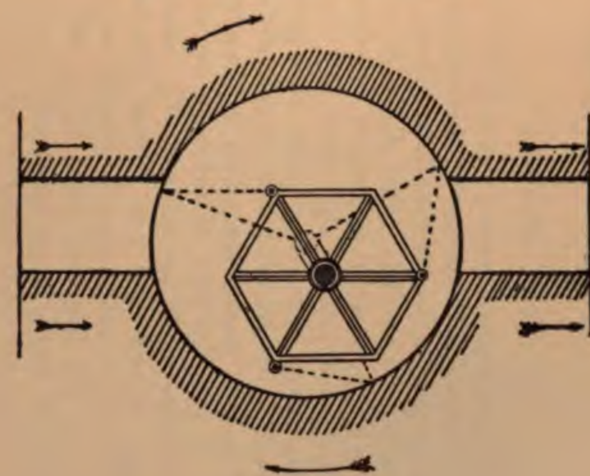


Fig. 192.—Lemielle Ventilator.



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Lemielle.

(Fig. 192.) This is of more recent design than Fabry's and has been constructed for dealing with larger quantities of air. It consists of a six-sided drum moving about a vertical axis, to which three shutters or wings are attached by means of hinges placed at alternate corners of the hexagon. The outer edge of these wings is joined to two connecting rods, which turn round their centre in such a way that the wings can set themselves to the ever-changing position of the hexagonal drum. A ventilator on this principle was described in 1869 as being at work in county Durham. The machine was 23 ft. diameter and 32 ft. high, and only worked at a low velocity, namely, ten revolutions per minute, although that was considered a fair speed. The useful effect averaged 35½ per cent., and in some special experiments made to test its capabilities it was found that the re-entries of air were nearly one-third of the theoretic quantity that ought to be discharged from the mine.

The Lemielle ventilator has been very popular on the Continent. Twenty years ago it was applied at a hundred mines in France and Belgium, and said to be doing good work. Its advocates urged that the slowness of its working brought the leakage to a minimum; and, as to quantity, that was merely a question of size. The experiments made in England, and referred to above, scarcely speak so favourably. That in Durham was removed 1883.

Cooke.

(Fig. 193.) This ventilator consists of a pair of cylindrical casings, placed side by side, in which revolve eccentric cylindrical drums. Two swinging shutters suspended at, and oscillating about, a shaft, receive motion from the crank in such a manner as to be always close to, but not in absolute contact with, the eccentric drum, the shutter thus seals the outlet while the air is being drawn in from the drift leading from the mine. The eccentricity of the drums is about one-fourth their diameter. They are about two-thirds the diameter of the casing, and the width of both casings and drums is about one-half the diameter of the casing. The pair of drums are placed

opposite each other on the driving shaft, so that revolving mass is balanced and the discharge of air equ lised. The amount of clearance or play between revolving drum and the casing of the ventilator intended to be not more than ¼ in. both at the ends an the circumference of the casing, and also between the dr and the shutter. When this ventilator was introduced public notice it was stated that experiments had sho that, with a theoretic maximum displacement of 4, cubic feet per revolution, 4,166 cubic feet of air actually discharged, and upwards of 60 per cent. use effect had been obtained.

The experiments were made at the Upleatham a Lofthouse Ironstone Mines, belonging to Messrs. Pe and Co., under the supervision of the manager, William Cockburn. The actual results were as follows: Dimensions in both cases 22 ft. diameter and 11½ ft. wi Lofthouse—revolutions per minute 26 and 26, water gau in inches 1·12 and 1·00, cubic feet of air per min 101,308 and 96,757, useful effect per cent. 64·00 and 59· Upleatham—revolutions per minute 27 and 29, wat gauge in inches 3·25 and 1·56, cubic feet of air per min 88,900 and 120,816, useful effect per cent. 61·18 and 58· Showing an average useful effect of 60·71 per cent. against these results, presented in 1875 the North England Committee, six years later, give a very differe report as to the working of a Cooke ventilator at Hutt Colliery, Durham, the useful effect being only 37·33 p cent. (See paper by Mr. Daniel in the *Transactions* Mechanical Engineers for 1875.)

Root.

(Fig. 194.) This is described as a rotary air co pressing machine, as distinguished from a fan whi throws off the air by centrifugal action, in princip analogous to a blowing cylinder, with this difference, th the air is expelled constantly in one direction, and in fo distinct volumes at each revolution of the blower; b with a blowing cylinder the direction of the current of is altered at each end of the stroke. The position of t blower, therefore, is between the fan running at a hi

FIG. 193.—COOKE VENTILATOR.

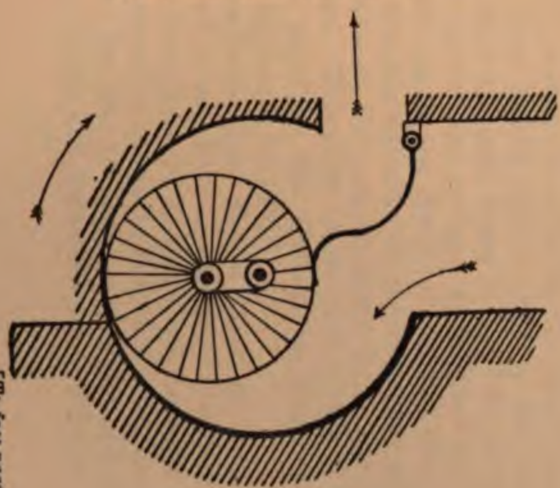
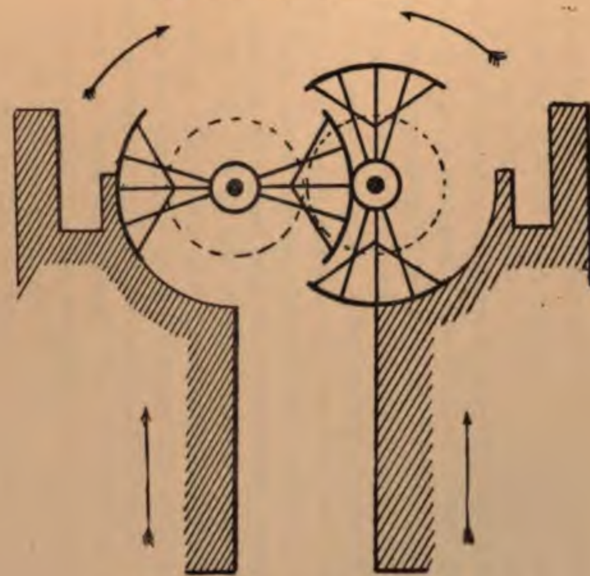


FIG. 194.—ROOT VENTILATOR.



[To face page 174.]

velocity, delivering a large volume of air at a low pressure, and the blowing cylinder with a piston working at a slow speed, expelling a small volume of air at a high pressure. First extensively used in America for smelting and similar purposes, it was introduced into England fifteen years ago, and has been largely adapted to furnaces, smiths' shops, portable forges, &c., and has worked up to a pressure of 3 lb. per square inch. The leading feature of the ordinary Root's blower consists of two duplicate rotary pistons, fixed upon separate shafts and working in a casing which is provided with inlet and outlet openings, either at the top and bottom or at the sides, according to circumstances. The rotary pistons are maintained in their proper relative positions by gearing on the shafts, and they revolve closely together, but not in actual contact with each other nor with the casing. The principle has only recently been applied to mine ventilation, and the pistons were made 25 ft. diameter and 13 ft. wide. The clearance between the two pistons or between the pistons and the casing does not exceed one-eighth of an inch. Experiments show this ventilator to give a good useful effect.

Root's ventilator, the first of its kind erected, was tried at Chilton Colliery, near Ferryhill, in 1877, of the dimensions given above, and experiments produced some remarkable results. The revolutions per minute were twelve, thirteen, eighteen, twenty-one; the water-gauge in inches 2·75, 4·00, 5·00, and 4·12; the cubic feet of air per minute were 67,312, 74,928, 101,696, and 118,272; the useful effect per cent. being 56·30, 76·85, 64·19, and 51·40—thus showing an average useful effect of 62·185 per cent. But again the North of England Committee step in, and four years afterwards, experimenting with the same ventilator at the same colliery, tell a much less flattering tale. They show useful effect of only 47·84 per cent. (See paper by Mr. Carbutt in *Transactions* of Mechanical Engineers for 1877.)

This completes the second class of ventilating machines, and it may be said generally that, whilst the two foreign arrangements of Fabry and Lemielle fail in both requirements of efficiency and simplicity, there is no disputing the fact that in the two more recent and English appliances of Cooke and Root efficiency is obtained.

The writer will only venture to say at this point t
all fail as regards simplicity, and are more liable to bec
deranged than is desirable in a machine which ha
work continuously for years. For this reason they
placed in the second class in order of merit.

The third and last class includes all kinds of f
dealing with mine ventilation on the centrifugal princi
and although the writer may be wrong in holding
opinion that these are the best of mechanical ventilat
he has the great majority of mining authorities with hi
at least nine out of every ten machines in use belong
this class.

CHAPTER XIX.

MECHANICAL VENTILATION.

Centrifugal Ventilators—Their Action—Newton's first Law of Motion—Inertia of Matter—Definition of Centrifugal Force—Robertson on the Action of Centrifugal Pumps—Low Useful Effect—Appold's Experiments—Straight and Radial Blades—Straight and Inclined Blades—Blades curved Backwards—Why the Inclined Blade gives good results—Robertson on the curved form of Blade—Nasmyth—Size and Construction of Fan—Brunton—Two attempts at Mechanical Ventilation—Biram—Blades inclined Backwards—Experiments at Durham—Biram's Explanation of the Principle of his Fan—His Improvements in Winding Appliances—His Anemometer—The best Fans are those of Waddell, Guibal, and Schiele—Waddell—Construction of Fan—Admission and Discharge of Air—Curved and Proportioned Passages—Backward Inclination of the Blades—Is made large in Diameter and runs at moderate Speed—Schiele—Runs quickly and is small in Diameter—Form of Blades—Spiral Casing—Expanding Chimney—Admission of Air—Uniform Area of Passages—Results with a Schiele Fan—Guibal—Very largely used—Balance of Opinion in its favour—Made large in Size and has moderate Speed—Air Discharged into Expanding Chimney—No Spiral Casing—Adjustable Shutter—Form of Blades—Admission of Air—Accidents with Guibal Fan Shafts—Which is the best Fan Waddell, Guibal, Schiele?—Defect of the Waddell through Open Running—Cowper on the Spiral Casing—Bramwell on the Form of Blades and Spiral Casing—Guibal on the proper Construction of Fan—Advantages of the Expanding Chimney—North of England Report of the various Kinds of Fans—Difficult to decide which is the Best—Waddell, Schiele, and Guibal all do good Work—Francis Murphy's Champion Mine Ventilator of America.

In some form or another, for merely producing a blast, fans probably are as old as the hills. They are so easily constructed, so simple and effective in operation, and have so few parts that can by any possibility get out of repair, that in early times they secured popularity, and in modern times have deservedly maintained it.

Their action may be briefly and simply explained. When the fan revolves, all the air within receives motion, and if such motion were similar to that of the fan, the air would simply revolve and no useful effect be obtained. But according to Newton's first law of motion "Every body continues in its state of rest or of uniform motion

in a straight line, except in so far as it may be compelled by impressed forces to change that state." This law asserts the inertia of matter or that quality inherent to matter whereby it has no power in itself to change its own state of rest or motion. Consequently, the tendency of all bodies revolving in circles is to rush off in straight lines, tangents to the circle of revolution, at every point o the circumference. This tendency represents the centrifugal force, which is neither more nor less than the tendency which a revolving body has to fly from its centre Water within a revolving pump, and air within a revolving fan, have this tendency, hence the terms centrifugal pumps and centrifugal ventilators.

When the revolving body is secured to a fixed centre then the centrifugal force cannot expend itself in rushing away, but exerts a pull upon the centre which is measured by the weight and velocity in feet per second squared ÷ radius. That is to say, the centrifugal force of a bod which revolves in any circle is proportional to the squar of the velocity with which it moves in that circle. By th term centripetal force is meant any force which draws revolving body to the centre, or counteracts the centri fugal force. The action then of the centrifugal ventilato is that the air within the fan refuses to move in a circl and in accordance with the law of motion rushes awa from the centre, towards the circumference, thus makin room for more air and keeping up a current.

About the time of the Great Exhibition of 1851, centri fugal pumps were brought prominently under notice, an were the cause of several instructive discussions befor the Institution of Mechanical Engineers shortly after wards. A Mr. Robertson, in a paper which he read i 1852, argued that centrifugal action was not an economic mode of applying power for raising water, and that th theoretical limit to the useful effect to be obtained by cen trifugal action alone was 50 per cent. of the power employe a loss of 50 per cent. of the power being caused by absorp tion of power in the tangential velocity given to the wate whilst the radial or centrifugal velocity alone is effecti in raising the water. But the practical limit of the usef effect is reduced to 75 per cent., or only 37½ per cent. the power employed, in consequence of the unavoidab

Fig. 195.—Straight Radial Blades.

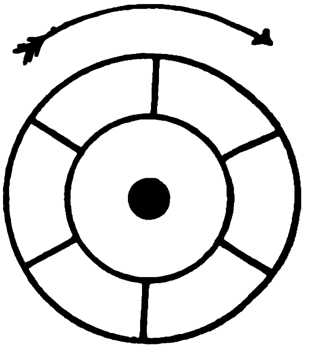


Fig. 196.—Straight Blades inclined Backwards 45°.

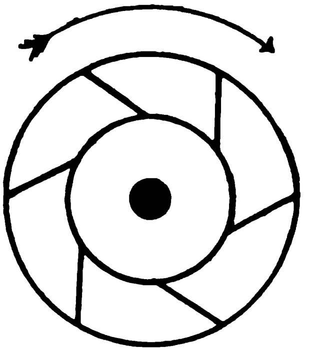
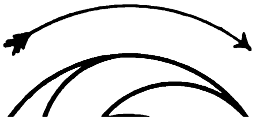


Fig. 197.—Curved Blades running into Circumference.



losses from friction and practical imperfections. This was Mr. Robertson's view worked out by most elaborate mathematical formulæ. Mr. Appold took part in the discussion, and gave the result of some extensive experiments made with centrifugal pumps having differently shaped blades—viz., straight and radial (fig. 195); straight and inclined backwards at 45 degs. (fig. 196); curved backwards and running into the circumference (fig. 197). The results were striking, fig. 195 giving 24 per cent. of useful effect; fig. 196 giving 43 per cent.; and fig. 197 giving 68 per cent. of useful effect. A glance will show the advantage of inclined blades over radial ones; the water operated upon reaches the circumference more expeditiously, and adapting this inclined straight line to the circle gives us the curved form of blade. Of course the explanation was that the waste of power was in consequence of the circular motion communicated to the water, the correct motion being that the water should glide to the circumference in straight lines by reason of the centrifugal force, without circular motion at all—all mere whirling round a centre being some power wasted. In reconciling his views with Mr. Appold's experiments Mr. Robertson, at the following meeting, said, in order to get the greatest ratio of useful effect, the blade must be bent back until the tangent at its extremity coincides with the tangent to the circle described by it, hence the velocity of exit is directly opposed to the tangential velocity, and, consequently, the actual velocity of the water is the difference between the two velocities; if the velocity of discharge equals the tangential velocity the water drops off at rest. When the blades are straight and radial the loss can never be less than half the power, because one-half is absorbed by tangential velocity, and the only means of raising the percentage of useful effect is by diminishing the velocity of discharge. But with curved blades it is quite the reverse, the greater the velocity of discharge the less is the difference between it and the tangential velocity.

The opinions held thirty years ago by such men as Mr. Robertson and Mr. Appold hold still.

As regards centrifugal pumps dealing with water, no one disputes that the blades should be curved backwards, but with centrifugal fans there is a great diversity of

opinion, and we have fans with blades of all forms, namely, straight radial, straight inclined, curved forwards and curved backwards.

Of course it must be borne in mind that air is a much lighter substance than water, and it is not a question of raising air to a certain height; but, practically, only clearing it of the fan. Still, although there is probably no need to carry the principle to the same extent, the tendency in the construction of blades should be in that direction. But we shall probably be better able to refer to the matter as we go along in touching upon each particular fan.

Nasmyth's fan (fig. 198) did not make for its author a name equal to that earned by his great work in connection with the steam hammer, but is remarkable in being the first attempt on a large scale to apply the principle to mine ventilation. The fan was 13½ ft. diameter, with eight vanes, each 3 ft. 6 in. wide and 3 ft. long. The fan worked within a casing, consisting of two fixed sides of thin wrought plate, entirely open round the circumference, the sides being 3 in. clear from the edges of the vanes, and having a circular opening of 6 ft. diameter in the centre of each, from which rectangular wrought-iron trunks were carried down for the entrance of air. The two air trunks joined below the fan, and communicated with the pit by means of a horizontal tunnel, which entered the pit seven yards below the surface. This fan was worked at sixty revolutions per minute, giving a velocity at the circumference of the fan of 2,545 ft. per minute. The results from this fan were considered so satisfactory that it was proposed shortly afterwards to construct one 21 ft. diameter. It gives one an idea how people were seeing that large fans were becoming necessary that whereas Mr. Nasmyth before the British Association some few years previously recommended fans 4 ft. 6 in. diameter, he actually fixed one 13 ft. 6 in., and afterwards proposed 21 ft.

Brunton's fan (fig. 199) preceded Nasmyth's, but was on a much less scale, and did not attain the same amount of success. It consisted of a horizontal wheel 9 ft. diameter, covering the top of the air shaft, with a large number of vanes, inclined like the vanes of a windmill or the blades of a screw. The air had access to the vanes on

the underside, and was expelled from the upperside of the fan. The plan was found to be unsatisfactory as a means of ventilation, and was entirely abandoned. In 1855, another fan of Brunton's was tried, and this time it was 20 ft. diameter, with blades radial and vertical. The construction was still that of a horizontal wheel placed over the pit. The air entered at the centre of the lower side, and was expelled at the circumference.

Biram's fan (fig. 200) was the first attempt to form the blades upon correct principles. Instead of following in the lines of Nasmyth and Brunton, and having radial blades, they were inclined backwards. One of these fans, about 24 ft. diameter was erected in Durham, and some experiments were given, as showing so low a useful effect as 12½ per cent., but the author of the experiment rather overdoes it by saying that from experience with other open-running fans he considers this percentage cannot be materially exceeded by any similar form of open fan without a casing. This means that Biram's was the best of the open-running fans; but the same writer admits further on that Waddell, with his open-running fan, obtained 39 per cent., and the North of England Committee have (December, 1881) reported experiments upon a Waddell fan showing nearly 53 per cent. useful effect. Biram's was not a fan likely to obtain a very high useful effect, as compared with others since introduced, but it was certainly equal to more than 12½ per cent., and its inventor deserves credit for having introduced into mechanical ventilators inclined blades.

Biram in his specification, dated 4th June, 1853, argues that as the efficacy of the fan must be mainly produced by the outer end of the vanes, it was desirable to have their depth, not as with Nasmyth's, one-half the radius, but only one-tenth, and increase their number to so many that a tangent from the root of one blade would just clear the top of the next. The idea being that each blade would exactly sweep out all the air between two blades whilst that portion of a revolution was made equal to the distance from one blade to the next. So that for every complete revolution each blade would sweep out a quantity of air equal to the capacity between all the blades. In this same specification there are illustrations and des-

cription of improvements in winding. It was proposed fix the drums upon which flat ropes are wound over th pit for drawing up coals, and applying the power of tw engines to cranks fixed at right angles to each othe upon the shaft of one of them, the other having also cranl at the end of the shaft similarly fixed, and the two bein connected by coupling bars exactly in the way four drivin wheels are connected in a locomotive engine. Th advantage of this arrangement is, besides dispensing wi a flywheel and extra pulleys over the pit top, the facili which it gives of enclosing the whole of the machine within a moderate sized building, and giving the engin man better sight, therefore better control of his engine Biram appears to have been indefatigable in his endeavou to effect improvements in the working and winding coals, and will always be remembered in connection wi the anemometer and ventilating fan which bear h name The fans that have come into most general us and deservedly so, are the Waddell, Schiele and Guiba and it is about these we now propose to speak. No speci mention will be made or sketch given of the Rammell fa because we may consider it practically as a double fan o the Waddell principle.

Waddell's fan (fig. 201) receives its air on one side onl at the centre, and is what is called open-running—tha is, it delivers the air all round the circumference. Th passages for air from the centre to the circumference ar nicely curved, so as to make the passage of air as easy a possible. The Waddell ventilator has its air passage through the fan with a gradually decreasing section fron the centre to the circumference, so that the velocity o rotation at any distance from the centre, multiplied b the sectional area of passage at that distance, should b constant, with the view of keeping the fan filled up to it circumference with issuing air, and preventing the possi bility of re-entries of air from the external atmosphere Some bell-mouthing is provided at the circumference t ease the delivery. The blades are inclined backwards an the whole structure revolves—that is, the blades an casing are all in one revolving piece. This fan is mad large and makes a moderate number of revolutions pe minute.

Schiele's fan (fig. 202) is made small in diameter and runs very quickly. The blades are inclined backwards for some part of their length, and at the tips are curved backwards. The casing is not attached to the revolving portion, and forms a spiral leading into an expanding chimney. Air is received on both sides. The blades are so constructed that the area for passages of air is uniform through the fan. The spiral casing gives a uniformly increasing space beyond the tips of the fan blades from nothing up to the full area of the discharge aperture, and in this way provides for the continual swelling of the volume of air in the casing, occasioned by the discharge of successive infinitesimal laminæ of air round the whole circumference of the fan. The writer, having some years ago to erect a Schiele fan at one colliery that had not been equal to the requirements of another colliery, was forced to take considerable interest in it. No other fan could well have been erected. There was not space, and the foundation was too treacherous for a heavy structure. The fan was 14 ft. diameter, and running at 100 revolutions per minute produced about 1,000 cubic feet of air for each revolution with 1·2 water gauge. It proved quite equal to the wants of its new habitation and gave no trouble. The special circumstances and the fair results obtained perhaps sufficiently explain a slight leaning towards this ventilator. Of three other Schiele fans which have come under notice, and all of which have been in constant work for several years, the following are the results:—Diameter, 12 feet; revolutions, 160 per minute; water gauge, 1·5 inches; quantity of air, 160,000 cubic feet per minute. Diameter, 9½ ft.; revolutions, 200 per minute; water gauge, 1·2 inches; quantity of air, 100,000 cubic feet per minute, being 500 cubic feet for each revolution. Diameter, 7 feet; revolutions, 275 per minute; water gauge, 1·5 inches; quantity of air, 60,000 feet per minute, being about 220 cubic feet per revolution.

Guibal.

(Fig. 203). Probably there are as many fans of this kind at work in this country and abroad as all other forms of ventilators combined, and certainly the balance of professional and practical opinion is in its

favour. It is made large and works at a moderate spe
The casing is not attached to the fan, and the air is n
discharged into a spiral, but leaves the fan at one particu
place through an adjustable shutter which can regula
the extent of opening. The air passes into an expandi
chimney. The blades of this fan are inclined backwar
and at the tips are curved so as to be radial with the c
cumference, having practically radial blades. In wid
the blades are parallel, and the air can be received eith
at one side or both. The Guibal fan has been unfortuna
in several cases in the shaft breaking. At one colliery
Yorkshire two steel shafts broke in two years. It do
not appear that the shaft was, either in material or in si
insufficient for its work, because, for a fan 46 ft. diamet
and 15 ft. wide, the material was steel and the diamet
21 inches, which would give an enormous transverse a
torsional strength. But it did appear that the constructi
was bad, because a third shaft of wrought iron has alrea
worked longer than its two predecessors. The difficul
seems to be the making so large a shaft sound, and a go
plan for such large masses would be to have them hollo
and manufactured from Whitworth compressed ste
Some ten years ago a screw propeller shaft for engin
indicating upwards of 5,000 horse power was made hollo
of compressed steel and has given good results. Anoth
difficulty very common with such large fans as 46 and
feet diameter is the heating of the bearings, which is n
occasioned so much by the mere dead weight as by th
weight causing deflection of the shaft, and so preventin
it lying level upon the bearings. There are two remedi
for this—first, to make the shaft hollow and thus provi
a larger external diameter without increase of weigh
second, allowing in the fixing of the bearings for th
deflection of the shaft.

The point arises—here are three centrifugal ventilato
all largely adopted, and all constructed on different prin
ciples—which is right and which is wrong? Each has i
advocates, and probably the correct answer to the proble
is, None of them are exactly right, and they all do goo
work. The Waddell is correct in its curved passages an
its uniform areas, but is it right in the open running
Being quite exposed it is liable to be acted upon by

strong breeze, which will not assist its free running, and no arrangement can well be made for easing the delivery, and the air rushing out at the circumference at a good speed wastes power by the force with which it has to strike the atmosphere, and, being open all round, part of the delivery must be on the ground, and this striking and rebounding will cause eddies in the fan. Suppose an open running fan has a circumferential velocity of 6,000 ft. per minute = 100 ft. per second, and discharges 240,000 cubic feet of air per minute. If the blades are radial this air will leave the tips of the blades with this velocity, which represents an amount of stored up work sufficient to raise the whole mass of air to a height of 156 ft. above the fan. Reckoning 13 cubic feet of air to one pound, we shall have 18,460 pounds weight of air discharged each minute, possessing work equal to raising it 156 ft.—$18,460 \times 156 \div 33,000 = 87$-horse power wasted in discharging the air at this velocity. The discharge of air at a greater velocity than is needed to raise it to the required point above the fan is power wasted. In the Schiele and Guibal this height is the height of the chimney, but in the Waddell there is no chimney, therefore the resultant velocity of the air should theoretically just be sufficient to enable the air to fall from the tips of the blades. It is only fair to say that the North of England Institute place the Waddell fan very high on their list, as producing 52·79 per cent. useful effect—and not much better than this has been obtained in mine ventilation. The Schiele is correct in its small diameter and high velocity. There is no mechanical difficulty in running a fan at 200 revolutions per minute, and by reducing the size the machine itself is less ponderous, a less massive foundation is needed, and the whole affair occupies less space. The backward curvature of the blades seems to be following in the correct lines as laid down for centrifugal pumps, and the narrowing the blades towards the circumference, so as to give uniform area of air passages, is unquestionably correct. As regards the spiral casing there has been, and is, great difference of opinion. Guibal tried the spiral casing, and obtained unsatisfactory results. On the other hand, Mr. Cowper, ex-president of the Mechanical Engineers, said the spiral casing should be the correct form, and in an extensive

series of experiments made with fans, he obtained the best result, being as high as 75 per cent., with the spiral casing. At the same time, however, Mr. Cowper stated that the fan with which he obtained the best results had straight radial blades, which would seem to show that the form of blades is, after all, not material. Mr. Cowper also thought it an unnecessary expense to employ a large fan for ventilating a colliery, when the same extent of ventilation could be obtained at less cost with a small fan running at a high speed, and he considered the small fan would be equally applicable and equally economical in working. Mr. Bramwell, another ex-president, said the spiral form was not only correct in theory, but it had been conclusively established in practice as the proper form; and curving the vanes forward at the outer extremity was wrong, and would diminish the results obtained from the power expended in driving the fan. The Guibal fan at first was made with the casing closed all round the circumference, except at one point where the air was allowed to be discharged, but this was found objectionable, because the air was discharged at the high velocity of the circumference of the fan, and thus carried away an important store of force, and the partial utilisation of this force has been effected by making the casing of the ventilator terminate in an expanding chimney. By this plan, the air entering the base of the chimney at a high velocity is made to leave the top of the chimney at a reduced speed proportionate to the increased area of the outlet, and consequently a considerable amount of power is thereby restored which would otherwise be carried off. This expanding chimney is an advantage, and is possessed by the Schiele and the Guibal in common. The principle of this expanding chimney is important. In consequence of it the air from the fan is not passed directly into the external atmosphere, but has its velocity gradually reduced, the object being to minimise the loss of power. The action within this expanding chimney is that momentum is converted into pressure. The particles of air move more and more slowly, and finally encounter the inert atmosphere outside. Here they are crowded together, the space becomes more densely packed, and finally this reduced momentum terminates quietly in an increase of pressure.

If the air rushed out unaided by the expanding chimney it would meet with much greater resistance; it would set up eddies, and would be clogged in every direction, taxing the engine and requiring more power. The spiral casing would seem to be a natural continuation of the expanding chimney, inasmuch as the air can leave the fan at any point of the circumference, and make its way through a gradually expanding passage to the chimney, and then to the external atmosphere. Guibal also attached an adjustable shutter to regulate the size of outlet from the ventilator, according to the various conditions of volume of air required and resistance to be overcome. Experiments were made to show the advantages derivable from the chimney and the shutter, and without either chimney or shutter the percentage of useful effect was 31, with the chimney it rose to 57, and with the shutter it rose still further to 61. With regard to the two points in which the Guibal fan differs from the Schiele, namely, in the concentric casing and the form of blades, Guibal argued, having first proved by experiments that his casing and blades were right, that the more removed the casing is from the extremities of the vanes, the less proportion of the total air in the casing in driven directly by the vanes, and consequently the less effective result is obtained from the centrifugal force. Then, as to the vanes, any backward curvature of a vane tends to reduce the effect of centrifugal force in propelling the air, and might answer for an open running fan, but not one in which the air can only be delivered at one point. And in the Guibal fan a forward curvature of the extremity of the vanes is adopted for the purpose of correcting the injurious effect resulting from the inclination of the vanes backwards—the inclination backwards from the radial line being designed to avoid the blow that would be produced by the entering air upon the vane if the vane were placed radially.

Thus ends the chapter on centrifugal ventilators, and it is certainly no easy matter, especially amidst so many contradictory arguments, and even results, to decide which is the best, because the advocates of all the three fans, viz., the Waddell, the Schiele, and the Guibal, can produce results of experiments placing their particular fan

far beyond all the rest. The North of England Instit Committee in their report, December, 1881, do not ren much assistance in deciding which is the best ventilat the Guibal varying from 40 to 52·95 useful effect, Schiele from 46·12 to 49·27, and the Waddell, the only of the kind that was tried, showing 52·79, whilst antiquated and much abused Struvé actually heads list with 57·80, and Cooke's, which was given in 1875 64, falls in this report to the bottom of the list, with useful effect. What can one do or say amidst such a m of confusion, which proves clearly only one point, and t is that experiments do not prove which is the best f In discussing the matter perhaps as wise a course as a has been adopted in presenting fairly opinions drawn fr eminent authorities on both sides and thus leaving t subject with the reader. All these three leading fans good mechanical ventilators, have produced high use effect, and are all, as shown by the large number at wo deservedly esteemed.

AN AMERICAN MINE VENTILATOR.

Since the chapter on centrifugal ventilators was co cluded, as then supposed, an intelligent and appreciati friend in far-off lands—Mr. John H. Harden, of Phœni ville—has kindly forwarded some particulars of appliance which has attained such pre-eminence in t United States as to have won for itself the title Champion Mine Ventilator of America. Although on introduced by the inventor, Mr. Francis Murphy, a fe years ago, it has already been extensively adopted Pennsylvania, Virginia, Ohio, Michigan, Indiana, Illino Iowa, and all the mining districts. The inspectors mines have reported highly in its favour, and the collie engineers deem it an excellent ventilator.

In construction it comprises two revolving whee working upon the same shaft, and placed about the di tance of their diameter apart. The driving pulley is one end, and in order to attain a high speed it is co nected to the engine with strap gearing. The air ente between the two wheels, and passing into the inlet each, which is about two-thirds the external diameter, expelled at the circumference. The appliance is n

large, and is easily pulled down or erected, and requires next to no foundation. A special feature is that, without stopping or changing the motion, it can be reversed from exhausting to blowing, and *vice versa*. It is so constructed that the blades do not oppose any flat surface to the air in the direction of the motion, and their contact with the air moved is reduced to a minimum. In fact, the blades of this machine are constructed on the lines argued in this chapter; they are curved backwards and run into the circle of the circumference. The sizes vary from 4 ft. diameter to 14 ft., and the speed from 600 revolutions per minute to 200—the circumferential velocity being about a uniform 7,500 ft. per minute. The theoretic capabilities vary from 44,000 cubic feet per minute to 500,000, and the useful percentage from 60 to 80. The bearings for the fan shaft are swivelled, and lined with Babbitt's metal, and no trouble is caused by heating.

It is very gratifying to obtain from so great a distance such interesting information, and it is pleasing to know that our American cousins are endeavouring with so much success to introduce a good ventilating machine. We shall be glad to hear more of it. Unfortunately, the particulars came to hand too late for the ventilator to be included in the illustrations.

At the Pagebank Collieries of Messrs. Pease, in the county of Durham, Mr. A. L. Stevenson has removed a Lemielle ventilator, and is erecting an improved Guibal fan made of wrought iron, blades and all. In the centre there is a diaphragm, and air enters on both sides. The fan is the first of its kind, and is 20 ft. diameter, and proposed to run if need be 100 revolutions per minute. The design is Mr. Stevenson's, the manager of the collieries.

CHAPTER XX.

MECHANICAL VENTILATION.

Motive Power and Useful Effect—Turbines—The general Motive Power is Steam—Good Opportunity for Mechanical Engineer—Advantage of Spare Engines—One Engine House—Separate Engine Houses—Breaking of Crank Pin—Arrangements for Expediting Disconnection and Re-connection—Bridgewater—Fan should not be difficult to change the Position by Hand—Fan Engines should not Work too long without Changing—Spare Engine should be kept in Order—Strokes of Fan Engines—Fans with Engines coupled Direct—Fans with Strap or Rope Gearing—Schiele Fans at Rainford—Size, Speed, Water Gauge, and Quantity of Air—Work Noiselessly—Small Expense for Oil or for Repairs—Advantages of Rope Gearing—Experience with Straps—Piston Speed of Fan Engines—Fan Engines should work Expansively and Condensing—Waste with Non-expansive and Non-condensing Engines—Simple and Compound Engines—Compound Engine the more Expensive at First, but more Economical in Working—Limited Expansion in Simple Engine—Unequal Strain upon Crank Pin and Unequal Temperature in Cylinder—Advantages of the Compound Condensing Engine — The Indicator — Watt — Richards—Hopkinson — Diagrams from Non-condensing and Condensing Engines—Horse-power—Nominal—Actual or Indicated—Useful—Horse-power of Ventilation—Water Gauge—Percentage of Useful Effect—Method of calculating Useful Effect—Table of Velocities and Water Gauge and Quantities of Air—The only absolutely Correct Method of comparing Useful Effect of Fans—Furnace Ventilation most Effective when Upcast Shaft is Deepest—Fan Ventilation most Effective when Downcast Shaft is Deepest.

In some few cases where the power of falling water can be utilised turbines might easily and economically be made the means of transmitting power to fans or other ventilators, but we may commence by taking it for granted that, practically in every case, steam is the motive power. There are few operations in which more scope is afforded for adapting the very best types of steam engines than for ventilating, because the work is continuous, and, to all intents and purposes, uniform. The intermittent characteristic of winding engines is absent here, and the engineer has a fair field, and needs no favour for the display of his talent. In the early days of mechanical

ventilation the engines were all coupled direct, and mostly worked non-condensing and almost non-expansive. But as fans were more generally introduced increased in size, producing greater currents of air, and having to work at higher speeds, alterations, in most cases improvements, were effected in the engines. In some instances only one engine is attached to the fan, and although after many years no great inconvenience has been occasioned, it is a risky kind of business, and not to be recommended. Engines do get out of order, and repairs cannot always be postponed to the week end. Making such repairs during the working portion of the week means a total suspension of labour, and throwing an entire colliery idle is a serious matter.

The general practice is to have two separate engines either placed in the same engine-house, and such as can be attached to the same crank pin, or else placed in different engine-houses on opposite sides of the fan, and such as can be attached to different crank pins. This latter arrangement is the preferable one, because if a crank pin breaks both engines are not made useless, and in separate engine-houses inspections and repairs can more conveniently be made. At an important Lancashire colliery, the only mishap ever experienced with ventilating machinery was the crank pin breaking, and there was no spare one. Whether placed in one engine-house or two, the arrangements should be such that disconnection and re-connection may be made in a minimum of time. At the Bridgewater Collieries, where both engines are placed in the same building, an adjusting screw is fixed over each connecting rod. This screw, when the connecting rod is at work, does nothing; but when the engine is disconnected will draw the rod up, and hold it out of the way for weeks and months, and lower it down into position when required. This appliance is simple and efficient. In some cases also the fan itself is so difficult to move round that a number of men have to go into the drift, sometimes into the fan itself, to shift it to suit the position of the engine with which it is being connected. This should not be—it is slow work and scarcely safe. The requisite leverage appliances should be fixed to enable the fan to be moved easily and expeditiously.

Some time must necessarily be lost in changing engine, unless the system were adopted of having separate fans and separate engines put side by side, that one could always be started before the other stopp Even with the present system the time occupied need exceed half an hour, and it will tend to lessen the time changing if no one engine is allowed to work contin ously more than six weeks or two months, taking care have the idle engine always in readiness to work. spare engine is a delusion if not in order. Changi engines oftener ensures their more regular inspectic and therefore they are less likely to get out of ord Even with engines "a stitch in time saves nine."

Fan engines have usually had short strokes, the id being to obtain power without having a high piston spee but with long or short strokes the number of revolutio will be the same with two changes of motion in the pist for each revolution, and there seems no good reason wl fan engines should not have the excellent proportion length of stroke equal twice the diameter of the cylinde The shorter a cylinder is, the more proportion of surfa there is for condensation, and the higher proportiona waste from clearance at ends of stroke and in passage For fans such as the Waddell and the Guibal, with hig circumferential velocity but comparatively small numb of revolutions, engines coupled direct do well enough, an that is the practice generally followed. For fans such a the Schiele, which are small in diameter, and therefor to have as high a circumferential velocity must make man more revolutions per minute than the others, it is scarcel the best practice to couple the engine direct; and th system in a good many instances has been applied wit excellent results of driving the fans by broad straps. I this way we can run the fan at a maximum and work th engine at a minimum speed.

At the collieries of the Rainford Coal Co. there are tw Schiele fans at work, equal, perhaps, in their workin results, to any fans in existence. The manager, Mr Thomas Y. Greener, has in the most handsome manne placed at the disposal of the writer such information as h had at command, and has expressed not only willingnes but desire that further experiments should be made t

test and complete the information already obtained. These experiments will be made and presented at some future time. Meanwhile, the following particulars are of service. One fan is 7 ft. diameter and running 275 revolutions per minute; 1·5 in. water gauge gives over 60,000 cubic feet of air. The other fan, 9½ ft. diameter, running 200 revolutions per minute, with 1·2 water gauge, obtains now 90,000 cubic feet of air, and when the fractional resistances of the mines were less, obtained over 100,000 cubic feet. Both these fans are worked by strap gearing 3 to 1. The engines and fans are practically noiseless, have worked for several years, and have necessitated scarcely any repairs. The cost of oil, &c., which in some cases is very serious, only amounts at this colliery to a few shillings per week. These fan arrangements are so excellent in every respect that what is said here is by no means the last word about them. Rope gearing could probably be worked in the same way, with this extra advantage—that having six or eight ropes the breakage of one would matter nothing, whereas the breaking of a strap matters a good deal. Users and advocates of straps would say, and with truth, that straps do not break and need not break. The Rainford straps have been working for years and have given no trouble.

It might be said with regard to fans and their engines that for massive ventilators 40 or 50 ft. diameter straps or ropes could hardly be recommended and are not necessary, because the number of revolutions per minute is not large. But for small quick-running fans, making from 100 to 300 revolutions per minute, such a speed would not tend to economy in the engine, and either strap gearing or rope gearing is essential. A fan engine, working, as it does, day and night for weeks and months without ever stopping should not have a piston speed exceeding 250 ft. per minute. In all cases the engine should work expansively and condensing. If we have no expansion it is simply throwing into the atmosphere every revolution two cylinders of full pressure steam that has done no work at all; and working non-expansively at even moderate speeds, it is impossible for the exhaust valves to free the cylinders quickly enough, and the inevitable result is high back pressure. If we work non-condensing we must at least

waste 15 lb. pressure of all steam that passes through steam cylinders.

Some engines are simple and others compound. class has its advocates, but probably the compound en which is most expensive at first, is the more econom The ratio of expansion in a simple engine with one cyli is limited, because of the unequal strains upon the en during the stroke, and also from the unequal tempera This is readily understood, because if we expand stea one cylinder six times the strain upon the crank pin, will be six times as great at the beginning of the strok at the end, and the temperature also will be highe the commencement of the stroke, which is objection because the end of the stroke one way is the beginnin the stroke the other way. For these reasons chiefly compound engine for high rates of expansion is consid the best. It gives more uniform strain upon the en during the stroke, and adapts the temperature of cylinder to the steam passing through it. It is only to add that a compound engine gives the steam a gre distance to travel and affords more surface for injur condensation. But taking all things into considera we may say, as regards motive power for fans, the mode of transmission is a compound condensing en with a piston speed not much exceeding 250 ft. per min

In ascertaining the amount of motive power transmi to a fan we make use of the indicator, and this seem opportune a time as will occur for touching briefly, let us hope clearly, upon this useful piece of mechan Invented by James Watt, for the purpose of enabling workmen erecting engines too far from home to have personal supervision to ascertain the accurate workin the engines under their charge, it fell into disuse for s time after his decease, but it has been much improve late years, and is now universally used, and no engine at all competent who does not understand its construct and its use. We present figures of Watt's orig indicator, and two which perhaps represent as well any others modern improvements, viz., Richards' Hopkinson's.

Watt's indicator (fig. 204) as described by hims consists of a cylinder about 1 in. diameter and 6 in. lo

Fig. 204.—W

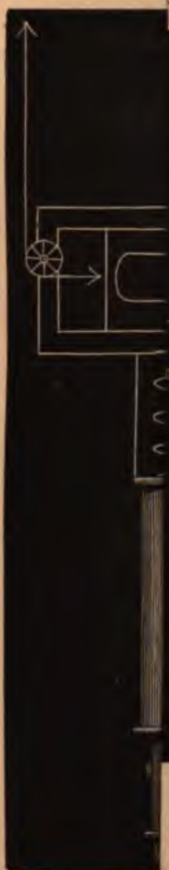
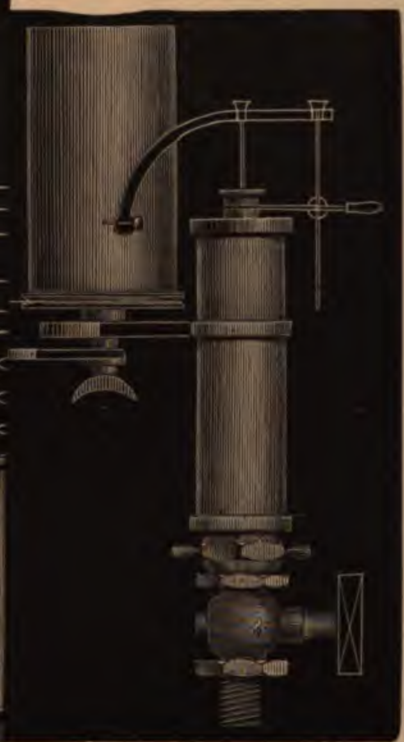


Fig. 206.—Hopkinson's Indicator.



[*To face page* 194.]

exceedingly truly bored, and has a solid piston accurately fitted to it, so as to slide easily by the help of some oil, the stem of the piston being guided in the direction of the axis of the cylinder, so that it may not be subject to jam or cause friction in any part of its motion. The bottom of this cylinder has a cock and a small pipe attached to it, which, having a conical end, may be inserted in a hole drilled in the cylinder of the engine near one of its ends, so that by opening the cock a communication may be effected between the inside of the cylinder and the indicator. There is also a frame with a steel spring attached to it by one end, the other end being fastened to the piston. The cylinder is open to the atmosphere at the top, and the piston remains at rest when the steam pressure is equal to that of the atmosphere, but rises or falls as the pressure becomes greater or less than the air pressure. The amount of the rise and fall will be determined by the strength of the spring, which must be tested, and a graduated scale, together with an index at the end of the piston serves for measuring pressures. So ends Watt's description, which is evidently incomplete. But if the index at the end of the piston be replaced by a pencil, and a board carrying a sheet of paper be caused to move to and fro underneath the pencil, with a motion identical with that of the piston of the engine, but on a smaller scale, the direction of the motion of the pencil being vertical and that of the board being horizontal, it will be found that the pencil traces upon the paper a closed curve, which is Watt's diagram of work.

The general principles of all modern indicators agree. The paper on which the diagram has to be taken is folded upon a barrel, which can revolve. The action of the steam within the cylinder of the indicator forces the piston up and along with it the piston-rod and pencil. The string which is coiled round the revolving barrel is attached to the engine, and communicates the backward and forward motion of the engine to the barrel, which consequently makes a backward and forward movement. The result of this combination of motions is that the pencil has traced upon the paper a diagram. This diagram of course differs as the steam is of a higher or a lower pressure, and as the engine works expansively or non-expansively, condensing

or non-condensing. On all diagrams we trace the atm spheric line, which is simply done by closing the indica tap, thus having no action either of vacuum or press upon the indicator piston, and allowing the indica barrel to revolve while the pencil traces the horizon atmospheric line. Any portion of the diagram above t line shows pressure, and any line below shows vacuu In a diagram from a non-condensing engine the diagr is entirely above this line, but in a diagram from a c densing engine the diagram is partly above, and sho pressure, and partly below, which shows vacuum.

Richards' indicator (fig. 205) is the most gener used, and is constructed with the view of getting as ste a movement as possible. The contention is that wh steam at a high pressure is suddenly admitted into cylinder of the instrument the pencil will rise with a je and will oscillate with a tremulous motion during the ti that it ought to be descending smoothly according to curve of expansion. Richards diminishes the piston str and multiplies the travel of the indicator pencil so as bring it up to the original standard, and uses a stron and shorter spring.

Fig. 205 shows the Richards indicator in positi connected to the engine cylinder. The practice whi extensively prevails of having pipes brought from bo ends and the indicator placed midway, so as to ta diagrams from both ends without changing position, convenient but not effective. Diagrams are worse th useless if inaccurate, and can scarcely be accurate if t indicator is at a distance from the engine cylinder. Bett far to have a little more trouble and obtain true diagra than to consult convenience and have wrong resul Hopkinson's indicator (fig. 206) is a more modern instr ment, has obtained excellent diagrams, and is constructed different principles from Richards'. This indicator has t motion of its piston transmitted to the pencil in the mo direct way possible, and without the intervention of a intermediate levers, joints, or frictional parts of any kin All the reciprocating parts are light, and the parts in co tact are few and simple. The inaccuracies attendant up complicated arrangements are avoided. There is not th friction which is a necessity of the multiplicity of parts

FIG. 207.—DIAGRAM FROM NON-CONDENSING ENGINE.

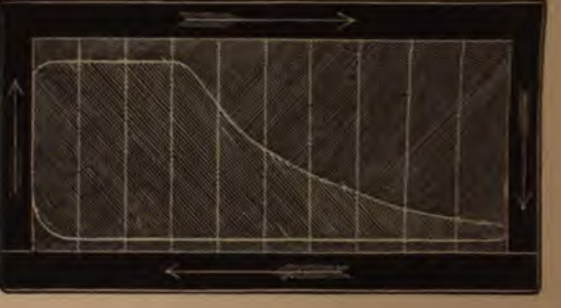
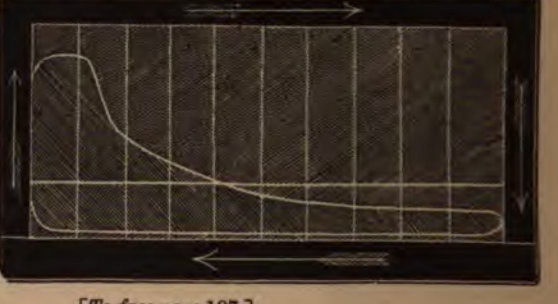


FIG. 208.—DIAGRAM FROM CONDENSING ENGINE.



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the transmission of motion, and there is not that wear and tear which will unavoidably take place with many joints in the course of time.

The writer is unwilling, and it would be unfair, to speak with prejudice against either of these excellent indicators. Having somewhat extensively used them both his opinion is that for very high pressures and speeds, such as locomotives, Richards' indicator is the best, but for moderate speeds, such as colliery winding, hauling, pumping, and fan engines, he finds Hopkinson gives the best diagram.

We will now suppose two diagrams to have been taken, one from a non-condensing engine and one from a condensing engine. The length may be anything, and is usually about 5 or 6 in., but whatever it is it represents the stroke of the engine. The vertical heights are represented to scale, that is to say, an inch represents so many pounds pressure, and the spring attached to the indicator piston has been constructed to the same scale. If the steam forces the indicator piston up 1 in. we know there is a pressure of 8 or 12 or 24 or 32 lb. according to the scale, and so we ascertain the pressure upon the diagram. Taking the non-condensing diagram first (fig. 207) we divide it into ten equal parts, and draw vertical lines, and mark within each space from the scale the pressure of steam behind the piston, measuring from the atmospheric line to the upper line of the diagram. Adding all these together and dividing by ten we get the average steam pressure behind the piston during the stoke. Then find the back pressure, which represents the retarding force of the exhaust, and is seldom less than 3 lb. even in good engines. We do this by measuring also from scale the distance within each space from atmospheric line to lower line of diagram; add all these together and divide by ten, and we have the average back pressure, which deduct from average steam pressure, and result is the average effective pressure of steam upon the piston throughout the stroke.

In the other diagram, namely from the condensing engine (fig. 208) we may proceed more expeditiously by simply measuring the vertical height between the spaces from lower line of diagram to higher line, and adding them together, divide by ten, and we have at once the average effective pressure upon the piston during the

stroke. Having found the average effective pressure of steam per square inch upon the piston throughout the stroke, we multiply this by square inches, area of piston, and again by speed of piston in feet per minute, and divide by 33,000 and we have the horse-power. In figs. 207 and 208 the highest horizontal line shows the supposed steam pressure on the steam gauge, which is always something above the pressure upon the piston. In fig. 207 the bottom horizontal is the atmospheric line. In fig. 208 the bottom horizontal is the zero line and the horizontal above it is the atmospheric line. In fig. 207 the cut-off is at one-third, and the expansion three times. In fig. 208 the cut-off is one-ninth, and the expansion nine times.

The term horse-power is used in engineering in various ways. We have nominal, actual or indicated, and useful horse-power, and no better opportunity will arise for explaining the difference. Nominal horse-power is supposed to give some idea of the size of an engine, but is rapidly and properly going out of use. In the early days of Watt, when speed of piston and pressure of steam were tolerably uniform, horse-power could be determined according to the size of the engine. But in these days, when speed varies from a few feet per minute to over a thousand, and when pressures vary to an equal extent, horse-power cannot be determined merely by size. Nominal horse-power now may be taken as representing a certain amount of piston area. One rule gives 11 square inches for each horse-power in a non-condensing engine and 22 square inches in a condensing engine. Actual or indicated horse-power is determined from the diagrams, and depends therefore on pressure and speed, and is the actual power exerted by the engine, including engine resistance. Useful horse-power represents the useful work done. In a winding engine this means the weight of coals, and in a pumping engine the weight of water raised per minute multiplied by the height. That engine is the best which with a given quantity of steam develops the highest useful horse-power.

There is no intention here to write a treatise upon the indicator, and the foregoing is almost sufficient for our purposes in connection with useful effect of fans. But it may be worth while to add another word as to what the indicator does and how it should be used. It tells us the

pressure behind the piston and in front of the piston at every point of the stroke. It tells when the steam and exhaust valves open and close. It shows whether the piston is tight or allows steam to pass. It shows whether the steam is wire-drawn in its entrance to cylinder and whether the exhaust is throttled in its exit. It shows us the power exerted by the steam during each stroke. The indicator tells us exactly what the engine is doing, and is to the engineer what the stethoscope is to the physician.

In using an indicator we must be careful to have the stroke corresponding exactly, except in length, to the stroke of the engine, and must have the indicator as near the cylinder as may be. The indicator piston must be tight, but move freely, and the piston must have been accurately tested to suit the scale from which pressures will be measured.

Having obtained these diagrams and obtained what we call the horse-power of the engine we must proceed carefully or else we shall not obtain a correct useful effect. Pistons have always a rod on one side, and sometimes on both, and, to be accurate, the areas of these rods should be deducted from area of piston. Some amount of power is needed to drive the engine against its own resistances, and in the best engines this will amount to 2 lb. per square inch, and in bad engines will amount to much more. To ascertain accurately the work that the engine can transmit we must ascertain the work done in driving the engine only, and this is done by disconnecting the engine from the fan, if strap gearing is used, and taking a diagram, which, worked out in the usual manner, will show the horse-power utilised in driving the engine, and so show also the actual horse-power that can be transmitted in the fan.

Now, we want the horse-power of ventilation, which is the quantity of air passed per minute multiplied by certain other figures and divided as usual by 33,000. The quantity of air should be measured in the fan drift, and to measure it accurately is not easy. Taking the velocity in the middle and multiplying by area will not do, nor is there any one point in the drift where the velocity can be taken; it varies so much at various points. The velocity must be measured at a very large number of points in the cross section of the fan drift and the average taken. This

average multiplied by sectional area will give the numb of cubic feet per minute, and this has to be multiplied b the water-gauge in inches, and by 5·2; and now we mu see what this means.

A column of water 34 ft. high is equal to an atmospher pressure of about 15 lb. per square inch, and a column water 1 in. high is equal to a pressure of 5·2 lb. per squa foot. The water-gauge, or as it is sometimes called, th syphon gauge, is a bent tube partially filled with wat which enables us to tell slight pressures, or slight depre sions. Suppose first for pressures, as gas, or air for smith fires. One end of the bent tube is open to the atmospher and the other end open to the gas or air whose pressure ha to be tested. The water falls in one leg and rises in th other, and the water-gauge is measured by the differen in level. The same in ascertaining the draught of chimney, or the current in a fan drift, the difference i level gives the water-gauge; and having multiplied th cubic feet of air per minute by the water-gauge in inch and by 5·2, we divide all this by 33,000, and have obtaine the horse-power of ventilation. Then, supposing th useful horse-power of the fan engine to be 100, an the horse-power of ventilation 60, the useful effect c the fan producing it would be said to be 60 per cent. T show what a fan is doing we must take the water-gauge a near as possible to the fan inlet.

We will take one example to show how horse-power c engine, horse-power of fan, and useful effect are calculate The engine is non-condensing, and measures 30 in cylinder, with piston-rod on one side 5 in. diameter, an 4 ft. stroke, working forty revolutions per minut Diagrams taken from both sides show an average pressur behind the piston of 30·5 lb., and a back pressure in fron of the piston of 4·3 lb., thus allowing an average effec tive pressure of 26·2 lb. per square inch. The are of a cylinder 30 in. diameter is 706·8 square inches, an the area of a piston-rod 5 in. diameter is 19·63 squar inches $\div 2 = 9{\cdot}8$, and $706{\cdot}8 - 9{\cdot}8 = 697$ square inches $\times$ $26{\cdot}2 = 18261{\cdot}4$. A speed of forty revolutions with strok 4 ft. means 320 piston feet per minute. $18261{\cdot}4 \times 320 =$ $5843648{\cdot}0 \div 33{,}000 = 177$, the horse-power of the engin including the power required to drive the engine agains

its own resistances. Diagrams taken from the engine running light show 12-horse power required for resistances in the engine itself, leaving a balance of 165 useful horse-power transmitted to the fan.

The work of the fan amounts to 205,000 cubic feet of air per minute, with 2·8 in. of water-gauge. $205{,}000 \times 2{\cdot}8 = 574{,}000{\cdot}0 \times 5{\cdot}2 = 2{,}994{,}800{\cdot}0 \div 33{,}000 = 90{\cdot}75$ horse-power of the fan; and as 165 is to 90·75 so is 100 to 55 per cent. of useful effect of the fan. But if we had taken the actual gross indicated horse-power of the engine, then, as 177 is to 90·75 so is 100 to 51 per cent. of useful effect of the fan. A good deal has been said and written lately that the present system of calculating useful effect of fans is misleading, and probably that explains the otherwise mysterious fact that each fan introduced has been proved to have the highest useful effect somewhere. The report of the North of England Committee, for instance, in its tabulated results, shows some striking differences between fans constructed on the same principle. The Guibal fan shows 40 per cent. useful effect, and another Guibal fan nearly 53 per cent. One Schiele fan shows 46 per cent. useful effect, and another Schiele fan 49 per cent. Any conclusions drawn from contradictory results such as these must to some extent be inaccurate. This kind of comparison is scarcely conclusive, because it does not take into account an important factor, namely, the natural ventilation of the mine. It is evident that with natural ventilation a positive quantity, that is in favour of the machine, a fan would show to better advantage than when the natural ventilation is a negative quantity, namely, against the machine.

We find fans constructed on the same principles, and even of the same dimensions giving widely different results. Mr. Wales, one of Her Majesty's Inspectors of Mines, in his annual report for 1880, draws attention to two Guibal fans, each 40 ft. diameter, at work in his district; one running 50 revolutions per minute produced 200,000 cubic feet of air, and the other running 52 revolutions per minute produced only 60,000 cubic feet of air. And we find even the same fan, working at the same pit, varying in the quantity of air, although the speed and water gauge are constant. At the Rainford Collieries a Schiele

fan produced in 1881, 100,000 cubic feet of air per minute, and in 1882 the quantity was reduced to 90,000 cubic feet per minute, although the speed and water gauge were the same in both years. A conclusive method of deciding which is the best fan would be to have a Guibal, a Schiele, and a Waddell placed at the same pit, and each worked continuously and alone for a week or two. This plan is not likely to be carried out, but at least one North of England Colliery has a Waddell and a Guibal, fixed and working. So far as these two are concerned there need be no trouble in deciding their order of merit. There is another plan which from its simplicity and apparent fairness has commended itself to many engineers, namely, to take the water gauge produced by a given circumferential velocity. The following particulars obtained impartially from nineteen fans in all parts of England may, from this point of view, be of some service:—

	Type of Fan.	Circumferential Velocity in ft. per minute.	Water Gauge in inches.	Cubic ft. of air per minute.
1	Guibal	3,468	1·125	120,000
2	Guibal	5,780	2·700	300,000
3	Guibal	3,769	1·100	76,000
4	Guibal	4,520	1·500	138,243
5	Guibal	5,635	2·900	278,000
6	Guibal	5,024	2·250	126,000
7	Guibal	4,470	1·750	122,848
8	Guibal	3,768	1·250	66,187
9	Guibal	3,770	1·250	63,000
10	Guibal	6,069	2·600	260,000
11	Guibal	6,047	3·750	250,000
12	Guibal	4,335	1·750	191,000
13	Waddell	5,652	1·750	110,000
14	Waddell	6,531	2·400	210,000
15	Schiele	6,452	1·800	147,000
16	Schiele	6,050	1·500	60,000
17	Schiele	5,970	1·200	90,000
18	Schiele	5,032	1·500	160,000
19	Schiele	4,077	1·600	67,730

The figures show that something else wants taking into account. Two Guibal fans with similar velocities have the same water gauge. (See 8 and 9.) Two other Guibal fans with nearly similar velocities have considerably different water gauges, the lowest velocity having the highest water gauge. (See 4 and 7.) Two Schiele fans have velocities 4,077 and 6,050, with water gauges 1·6 and 1·5, the lowest velocity having the highest water gauge. (See 16 and 19.)

In some introductory remarks it has already been stated that, as regards furnace ventilation, depth of upcast shaft is the most important consideration for efficiency, the volume of air circulated—other things being equal—increasing as the square root of the depth; so that furnace ventilation is applied more advantageously when of the two shafts the upcast is the deeper. This is clear enough, because the maximum efficiency of the furnace is at the bottom of the shaft and all colder air tends to rush there. But with the fan there is a difference—the maximum efficiency is at the top of the upcast, not the bottom, and the fan is more effective when of the two shafts the upcast is not the deeper. Fans which at work under correct conditions give good results will, if the arrangements are wrong, give an indifferent account of themselves. The current of air is much opposed to being dragged against its own inclination down hill to the bottom of a deep upcast, and wherever possible, therefore, the fan arrangements should be such that the course of the air will be in the natural direction of the mine itself.

In our remarks on mechanical ventilation we have simply in this chapter dealt with the manner in which motive power is transmitted to fans, and have taken the method of ascertaining useful effect as generally accepted. The only absolutely accurate method of comparing say two fans would be to have them working say for a week or two each at the same pit under the same conditions. All other methods of comparison will be more or less misleading.

Some remarks as to appliances for counting speed and recording ventilating pressure will comprise Chapter XXI. completing the section on mechanical ventilation.

CHAPTER XXI.

MECHANICAL VENTILATION.

Sudden Change of Ventilation much more likely with Fan than Furnace Danger with either Insufficient or Excessive Ventilation—Applicati of Counters—Where Counters are Deficient—Belgian Commissioners Messrs. John Davis and Son—Mr. Joseph Dickinson—Mr. Henry Hall Mr. Dickinson's Suggestion as to Automatic Apparatus—The Ris Explosion—Personal Investigation of Fans at Work in Manchest District—Some of them Partially Choked—Miners in one Instance h to be withdrawn—Singular Case of Neglect on part of Engineman Mr. Hall's suggestion as to Automatic Arrangement—Should not under Control of Engineman—Messrs. W. H. Bailey's Fan Recorder Application at the Townley Colliery, Burnley—Mr. Hall's Registeri Indicator at Bickershaw Colliery, near Manchester—Description of t Indicator—Inexpensive—Easily fixed—Can be placed in Manager Office, Half-a-mile away from Fan—Produces a Diagram showing Spe and Water Gauge for Twenty-four Hours—Description of Messr Bailey's Recorder—Is fixed in Engine-house—Each Diagram show Water Gauge and Speed for a Week—Suggestion that the Variati in Barometer should also be shown—Bailey's Recorder and Hall Indicator might well be used at same Colliery—Capabilities of Fans Difficulty in laying down Rules—Practical Results the best Guide Mr. Andrew Robertson—Professor Goodeve—Mr. Charles Cockson His Improvements in Guibal Fan—Rope and Strap and Spur Gearin

It has in previous chapters been mentioned that a advantage of furnace ventilation is that the curren cannot materially change its velocity suddenly, th change of action by a furnace being necessarily slow whereas with a fan, if it ceases work the current wi practically cease also in a very short time, and the venti lation be suspended. On the other hand, a fan possesse the advantage that if a greater or less current be sud denly needed, and for a short time only, the needf change can be effected almost momentarily, by increasin or decreasing the speed of the fan. The same princip which enables the speed to be altered at will, and to b an unquestionable advantage, is liable to allow the spe to alter without intention, and to become a disadvantag

At all establishments where fans are worked they are fitted with counters which register each revolution (at least this is so at nearly all, and those which have no arrangement ought to have), and a book is kept in the engine house in which are recorded the figures of the counter at a given time each day and night. By this means we know how many revolutions the fan makes in so many hours, and provided the counter is kept in good order, this is right so far as it goes; but it does not give any information of the speed of the fan at any minute—because, supposing we have registered 72,000 revolutions in the period from twelve midnight to twelve noon, showing an average of 100 revolutions per minute, there is no guarantee that this has been the velocity, which may have been lagging at 50 revolutions per minute at some time, and racing at 150 revolutions at another. And there is danger with either too high or too low a velocity. There is some reason to believe that one very recent disastrous explosion would not have occurred had there been a less current, and there is still stronger reason for believing that still more disastrous explosions have been caused by an insufficient current. It is easy to see therefore, that we might have in a given day, or a given hour, a number of revolutions representing a correct average speed, and have had during that day or hour a dangerously low, and a dangerously high velocity. What we require in mechanical ventilation, unless in specially exceptional cases, is uniformity of speed, and the ordinary counting arrangements do very little towards ensuring this. The Belgian Commissioners on Explosions of Firedamp recommended that each ventilating machine ought to be furnished with appliances to register automatically the variation of pressure. Messrs. John Davis and Son, of All Saints Works, Derby, who have been energetic and successful in their endeavours to effect improvements in all kinds of mining instruments, constructed for the Bestwood Colliery, in 1877, an apparatus with this object in view. No two men have urged the matter more strongly upon mining engineers than Mr. Joseph Dickinson and Mr. Henry Hall, both Her Majesty's Inspectors of Mines in Lancashire. Mr. Dickinson, in his annual report for 1880, said:—"The need of an automatic or self-regis-

tering apparatus for recording the periodical revolutions of ventilating fans and the height of the water-gauge in mines have come forcibly under my notice, and been represented by me when assisting in the investigation of the serious explosion in Risca Colliery, Monmouthshire. I have taken the opportunity of bringing the subject under the notice of the respective owners in my district, where fans are used as the ventilating power." And some time after this, in referring to the same subject, Mr. Dickinson further says:—"I have made personal inspection and enquiry respecting each fan in my district, and find three of them partially choked with water, the drainage not having been properly attended to, the miners having in one of the instances to be withdrawn in consequence. But the most striking illustration of the need of an automatic register is afforded by an occurrence which took place in my district in December, 1880, when the engine that worked the fan being found running slowly, the engineman, on being sought for, was found in a publichouse, for which neglect he was punished." His colleague in the Lancashire inspectorship—Mr. Henry Hall—at a meeting of the Manchester Geological Society, held at Wigan in January, 1882, said:—"It was most important that some automatic apparatus should be attached to all fans, to indicate their speed at all hours of the day, and that if possible such apparatus should be so placed as to be out of the reach of any interference or tampering on the part of the officials upon whose attention to duty the instrument was intended to act as a check. He believed the presence of such an apparatus would ensure greater watchfulness and care from engineers in charge of fans."

Mr. Dickinson placed his ideas of such an appliance in the able hands of Messrs. W. H. Bailey and Co., of Salford, who, after considerable endeavours to present an efficient apparatus, produced the automatic fan recorder illustrated in fig. 209. The first of the kind was applied to a Waddell fan working at the Townley Collieries of Messrs. Brooks and Pickup, near Burnley, and during the twelve months it has been in operation has quite fulfilled the hopes of all connected with it. The writer had the good fortune to see it in operation, and consequently is able to report on

FIG. 209.—BAILEY'S AUTOMATIC FAN RECORDER.

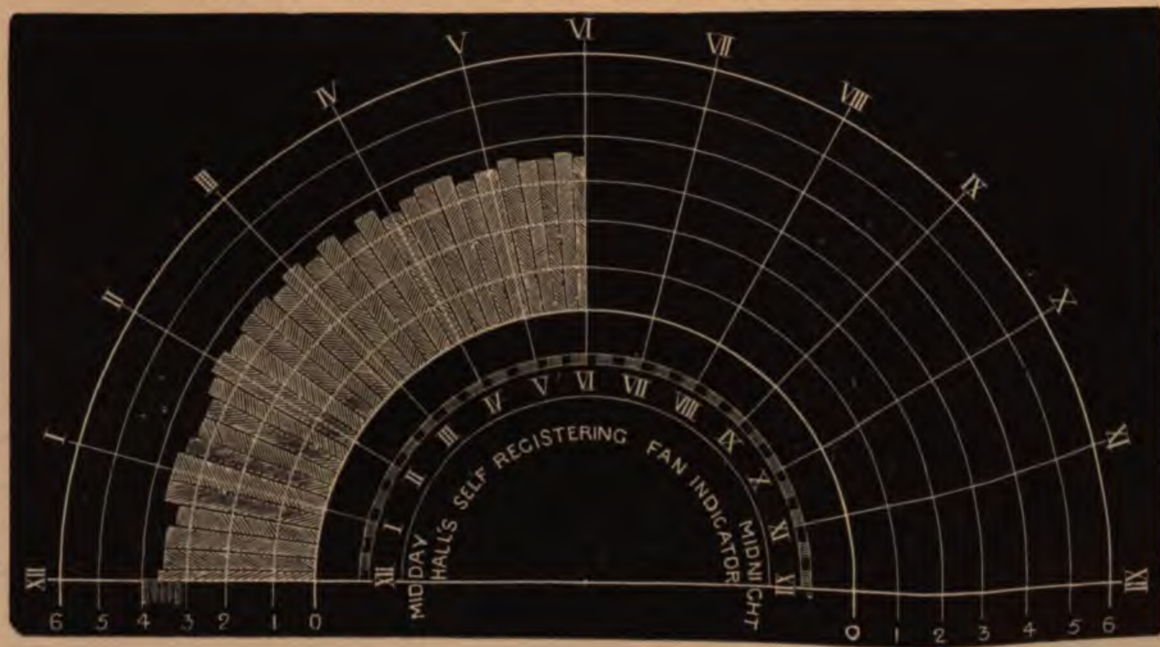
[To face page 206.]

its merits. Mr. Hall worked his proposals out himself, and has had one working for about a year attached to a large Guibal fan at the Bickershaw Collieries, Leigh, and has obtained equally favourable results. The writer has also seen this appliance in operation, and now proposes to give a few explanatory words with regard to each.

Mr. Hall, in his earlier description of this invention, termed it a tell-tale, which could be fitted up in a few hours by any ordinary colliery mechanic. It consisted of a specially designed water-gauge glass, which was placed in the manager's office and leading from there to the fan engine house—a distance which at Bickershaw was 250 yards, but which practically might be any distance greater or less than this—was a range of ¾ in. piping the open end of which was placed within the fan drift. Then a short branch of pipe was attached to these, and the open end placed in the fan engine house, where it was fixed so as to be within reach of some moving part of the engine which drove the fan, as, for example, within reach of the motion of the valve spindle. A small lever was attached to this pipe end, with a movement up and down, so as to open and close the outlet of the valve, and the motion of the engine valve spindle played against this, so that at each stroke of the fan engine the pipe end is opened for an instant, and a variation in the pressure of the atmospheric air in the long range of pipes takes place, causing the fluid in the gauge glass in the manager's office to fall to zero. But immediately the pipe end was again closed by the falling lever, the water-gauge glass showed the drag on the water-gauge of the mine, and the result was a perfectly correct and constant indication of the drag of the mine, and also of the number of revolutions the fan was making. This indication taking place in the manager's office, where it could be registered in a book as often as might be convenient, was entirely out of the reach of any interference on the part of the person responsible for the speed of the fan. The fluid in the gauge glass fell to zero at each stroke, so that it was only necessary to count these movements in the glass to determine the speed of the ventilating engine, and the height of one leg of the fluid over the other between the strokes was the measure or water-gauge of the mine. Such was the first arrangement, but

it was open to the objection that no permanent record was made; the speed and water gauge were only known at the time of inspection, and the arrangement was not practicable for a quick-running fan, such, for example, as the Norley Colliery, where the engine is coupled direct and makes 160 revolutions per minute, because the rising and falling of the fluid in the water-gauge would be so rapid that the speed or pressure could not be ascertained, and there would be nothing but confusion. To remedy these defects Mr. Hall suggested that when the fan to be indicated travelled at a great speed each fifth stroke need only be dealt with, so as to allow sufficient time to read off the drag of the mine between the indication of the speed, and this could be effected by the introduction of two small wheels worked at five to one, and deriving their motion from the drag crank of the engine. And it was further suggested for those who were anxious that the indications should be permanently registered, an eight-day clock could be added, fitted with a revolving brass cylinder, carrying a diagram paper, upon which a spiral line was drawn by a pencil, indicating the number of revolutions by the fan, and the water-gauge during any hour, day or night. What Mr. Hall has actually done is to so arrange his contrivance that a circular piece of paper is placed upon the face of a timepiece and round the circle has all the hours from one to twelve marked for day and night. This paper makes a complete revolution every twenty-four hours, and a diagram is placed upon it showing the speed of the fan and the water-gauge throughout the twenty-four hours. Each revolution is not recorded, but only each 250th—the needful mechanism being attached to the engine for reducing the speed to that extent. The fluid in the gauge glass rises and falls once to each 250 revolutions of the fan, and the rising and falling are shown upon the diagram by two vertical lines—the height of water-gauge being shown by practically horizontal lines, which are also traced upon the diagram. It might be objected that the distance between the office and the fan would affect the water-gauge; so it does, and the amount of that difference, which is uniform for a given distance, is simply ascertained when the appliance is set to work and added.

Fig. 210.—Diagram from Hall's Self-Registering Fan Indicator.



[To face page 208.]

Baileys' fan recorder is a modification of their well-known clock-recording apparatus, and consists of an eight-day clock which drives a drum about 8 in. diameter, to which is attached a paper divided into all the hours of the week. As the drum revolves, the fluctuations of the air passing through the mine are recorded upon it up to 6 in. water-gauge. The speed of the fan engine where the fluctuations occurred is also recorded upon the drum by means of a pricker which punctures the diagram once for each 5,000 revolutions of the engine which drives the ventilating machine. There is thus given in a concise form the speed of the engines and the fluctuations of the air pressure for every hour during the week's work. Mr. Dickinson, at whose suggestion Messrs. Bailey constructed the recorder, further suggested that it should be so contrived as to show also the fluctuation of the atmospheric pressure. By having a continuous record of speed, water-gauge and barometer, colliery managers would have very useful information placed at their disposal.

These two appliances are of equal excellence as regards their automatic registering of speed and pressure and of affording a permanent and continuous record of what a fan has been doing at any period of any day or night in any month of any year, and either one or the other or some similar contrivance should be attached to every fan. The difference between them is that Baileys' appliance can be fixed with convenience only in the fan engine house, under the control of the man upon whom it is intended to be a check, whilst Hall's self-registering fan indicator is placed in the manager's office—the engineman never sees it—and is practically independent of distance. A few pounds cover the cost of each, and probably some enterprising mining engineers may think well to adopt both, and place Baileys' in the fan engine-house and Hall's in the manager's office—the one answering as a guide to the engineman and the other imparting information to the manager.

Fig. 210 will give an idea of the action of Mr. Hall's arrangement, and is supposed to represent the diagram of pressure and speed from twelve o'clock mid-day to six o'clock in the evening. Only one-half the diagram form is shown; each really represents, as already explained

the work of a day and a night. The paper on which the diagram is traced is divided round the circle into twenty-four divisions, each division representing an hour, and each hour can have as many sub-divisions as are desirable, the usual practice being to let each sub-division represent one quarter of an hour. The paper is marked for water-gauge up to 6 in., and each inch is further divided into tenths, although these are not represented in the figure, to avoid confusion.

At the Bickershaw Collieries each 250th revolution of the fan is shown by a vertical line, but in the figure we have supposed only each 500th revolution to be marked, and with a speed in the fan of forty-one or forty-two revolutions per minute this would divide with a regular velocity each hour into five spaces. The irregular line round the circle represents the water-gauge, and is shown as varying from about 3·3 in. to 3·6 in. The variations of water-gauge are, perhaps, exaggerated, but these exaggerations only show with a little more clearness on the figure what the indicator does. Of course the diagram forms are changed each day at the same hour, and those taken off should be pasted in a book specially kept for the purpose, one book containing, when complete, the records of a whole year. It is hoped that the figure, along with the text, will have made the action of this self-registering indicator clear, but it is not easy to do justice to its merits or to understand its simplicity and efficiency except by personal inspection.

It was originally intended to say something as to the capabilities of fans of given dimensions, but it will probably be wiser not to attempt to lay down any rules as to the quantity of air which fans will discharge. Any such rules would only be correct under certain circumstances, and would simply mislead the reader, because everything depends on the conditions of the mine or mines through which the air has to pass. In Chapter XX. particulars have been given as to the actual work being done by nineteen fans of various kinds, varying in diameter from 7 ft. to 46 ft., and with velocities varying from a little over 3,000 ft. per minute to nearly 7,000 ft., and dealing with quantities of air varying from 60,000 cubic feet to 300,000 cubic feet per minute. Such practical results will be a far

better guide than merely theoretic rules. So many fans are now working that the most reliable lines for those who purpose erecting a fan are to obtain as much information from as many places as possible where fans are at work. No body of men are more willing to assist their fellows in matters of this kind than mining engineers.

Messrs. Walker Brothers, who have had a very large experience in fan construction and erection, extending over twenty years, in one of their excellent fan catalogues give the following table, showing the approximate volumes of air exhausted by fans according to diameter, and taken from actual experience :—

Diameter of Fans.		Width of Fans.		Volume of air per minute.
10 feet	...	3 to 4½ feet	...	20,000 cubic feet.
12 „	...	4 „ 5 „	...	35,000 „
16 „	...	6 „ 7 „	...	55,000 „
18 „	...	7 „ 8 „	...	65,000 „
20 „	...	7½ „ 8½ „	...	75,000 „
24 „	...	8 „ 9 „	...	85,000 „
30 „	...	10 „ 11 „	...	110,000 „
35 „	...	12 „ 13 „	...	150,000 „
40 „	...	12 „ 14 „	...	200,000 „
46 „	...	12 „ 15 „	...	250,000 „
50 „	...	12 „ 15 „	...	300,000 „

The very sensible note is attached to this table that the volume of air exhausted by fans depends very much upon the condition and dimensions of the airways in the mine. It not unfrequently happens as a consequence of this that fans of similar diameters do not give equal results at different collieries, and the above data are approximate only.

Thus ends what is to be said in this volume on mechanical ventilation, and the reader would probably be interested and find his general knowledge of the subject increased by the perusal of Mr. Andrew Robertson's papers, in the *Transactions* of the Mechanical Engineers for 1852 and 1853, already referred to, and Professor Goodeve's work on the *Principles of Mechanics*, both explaining why blades curved backwards in centrifugal pumps give good results. Also a paper in the *Transactions* of Manchester Geological Society for 1882, by Mr. Charles Cockson on centrifugal ventilators, in which powerful arguments are presented in intelligible form, favourable to the Guibal fan.

Mr. Cockson has about a year ago patented some improvement in ventilators, which would seem to combine whatever advantages the Guibal has, with the additional advantages of a quick running and balanced, therefore, noiseless fan. It would have formed an interesting conclusion to these chapters on mechanical ventilation to have been able, as was intended, to explain and illustrate what Mr. Cockson's improvements are and give some results. But as none of these improved ventilators are at work, it would be premature to make detailed reference to them. This much may be said: they will unquestionably have all the advantages of the ordinary Guibal, and it is hoped that a comparatively small fan, say 30 ft. diameter, will effect ventilation for which at present the ordinary Guibal has to be from 40 to 50 ft. The Wigan Coal and Iron Company have had large sized models, 4 ft. diameter, made of the ordinary Guibal, and the improved Guibal.

Of course the reason for confining the models to these two is quite clear. Mr. Cockson, in common with the great majority of mining people, believes the Guibal ventilator to be the best now in use, and his endeavour is to improve upon the best. The experiments have been of so satisfactory a character that the Wigan Coal and Iron Company are now erecting a fan 30 ft. diameter from Mr. Cockson's plans to ventilate their Alexandra Colliery. The engines will be of the usual condensing character, and to keep down the speed of piston, whilst allowing the fan to run at a high speed, rope gearing will be employed and power be transmitted through some fourteen or fifteen ropes. The erection of this fan will not only decide to what extent Mr. Cockson has improved upon the Guibal fan, but it will afford a good opportunity of ascertaining approximately the loss in friction from use of rope gearing. When a fan has to work at any such speed as 80 or 100 or even more revolutions per minute, direct connection between engine and fan is not desirable. Some kind of gearing must be adopted, and spur wheels will not do. There is only the choice between straps and ropes, and the latter arrangement is probably the better.

It has been said that there is a specially great loss of power in friction of rope gearing, but that can only apply in bad machinery, badly designed, and badly erected. Well

arranged rope gearing will work noiselessly and give off as high a useful effect as either straps or spur wheels.

Conclusion.

The writer has now, having tried to do his best, to place the result of his endeavours in the hands of his readers, and in so doing tenders his very grateful thanks to the many friends, and quite as many strangers, who have so kindly assisted and encouraged during the progress of the work. There is not much in it that is new; there is a good deal in it that is true, and there must at least be some points serviceable and interesting to the large body of students who are striving to become mine managers and engineers, and the larger number of practical men who have already attained to that honourable and distinguished position.

The volume only covers about half the ground. The second volume, now well in progress, will, amongst other appliances not dealt with here, specially include the machinery for pumping, hauling, and compressing air.

Possibly some of those readers who have so generously assisted in the preparation of this volume will not less kindly aid in the volume that is to follow.

A work even attempting to be a comprehensive treatise on *The Mechanical Engineering of Collieries* will fail in its object if the reader has simply put before him any one writer's individual knowledge and experience.

In so far as this production is feeble the writer will take the deficiency upon himself. And where it is at all worthy to be classed with the literary productions of a profession which stands pre-eminent as to its effect upon the material prosperity of England, the credit will attach to those who have placed at the writer's disposal much valuable information.

END OF VOLUME FIRST.

APPENDIX.

THE WIGAN MINING AND MECHANICAL SCHOOL.

(See Vignette on title page.)

THIS Institution owes its origin to a suggestion made by Mr. Edward, now Lord Cardwell, to his co-trustees of the Wigan Blue Coat National School in the year 1857. A conversation between those gentlemen and the directors of the Wigan Mechanics' Institution resulted in a visit to Wigan on the 27th October, 1857, of Dr., now Sir Lyon Playfair and the late Captain Ffulkes of the Science and Art Department, South Kensington. These gentlemen met the directors of the Wigan Mechanics' Institution in conversation, and afterwards attended a public meeting presided over by the late Mr. Henry Woods, then M.P. for the borough, at which addresses were delivered by Lord Stanley, now Earl of Derby, and Secretary of State for the Colonies, and Dr. Playfair. On the 6th of November, 1857, Mr. Birkenhead, subsequently Dr. Birkenhead, on the recommendation of Dr. Playfair, was appointed master. In 1858 Mr. Maskell William Peace was appointed honorary secretary and the Rev. T. F., now Canon Fergie, B.D., was appointed chairman, and it is owing in a large measure to their indefatigable efforts and powerful influence that the Wigan Mining and Mechanical School, during its twenty-five years' existence under their supervision has obtained a just recognition of its importance by | the representatives of the mining and other engineering industries of the district.

On the 2nd of August, 1858, the inaugural lecture was delivered by Mr. Birkenhead, the chair being taken by the late Mr. William Peace, and on that day week classes were opened under Mr. Birkenhead. During a temporary absence in London of Mr. Birkenhead the classes were conducted by Mr. Charles Whittle, and the first examination by the Science and Art Department was held in June, 1859, at which examination there were seven candidates in mining, six in geology, and three in chemistry. The proportion of successes was very high then, probably because few of the students were drawn from the artisan class. All the students were practically persons who enjoyed the advantages of what would be generally termed a good education, whereas in later years an increasing number have been coming from the working classes, and many such have received scarcely any elementary education.

On October 22nd, 1867, the school sustained a very severe loss in the death of its talented master, Dr. Birkenhead, who was cut off suddenly, at the commencement of what promised to be a most distinguished career; and in consequence of this event a meeting of the committee was held in the following month, who determined, on account of the small encouragement given by the public, and the want of appreciation of those for whom it was chiefly established, to close the school. But the Science and Art Department were unwilling that one of the oldest mining

schools in the kingdom, and established in so important a centre, should come to an untimely end, and Mr. Buckmaster was sent down to meet the committee and deliver a public address. The committee were not only willing but even 'anxious' to continue their efforts, and public enthusiasm was quite aroused at the public meeting. The result was that it was decided to re-open the school under the joint direction of Mr. Ralph Betley, F.G.S., who had been specially trained at Chester, as a science lecturer along with the late Dr. Birkenhead, and Mr. C. M. Percy, Mem. Inst. Mech. Eng., F.G.S. who for several years had been a regular student of the school. The classes were re-opened in January, 1868, with a considerable accession of members, and this number has been increasing ever since.

Holding the classes at the Mechanics' Institution had been found inconvenient in consequence of the number of public entertainments held in the building, some of them requiring the whole of the premises, and a new start was made in the Commercial Hall, now the Conservative Working Men's Club. Then the old Town Hall was occupied, and afterwards the old Grammar School, both of which erections have passed away. For several years comfortable rooms were used by the school in Hope-street, but it had long been felt by the Committee that the Wigan Mining and Mechanical School ought to have a permanent habitation of its own.

A building committee was accordingly formed in 1875, with Mr. Alfred Hewlett, of the Wigan Coal and Iron Company, as chairman, and Mr. G. L. Campbell, of the Central Association for dealing with Accidents in Mines, associated with Mr. Maskell Wm. Peace as joint honorary secretaries, and an extensive scheme prepared. This scheme proposed the purchase of land and erection of a building suited for the increasing requirements of the school. Many very handsome donations were promised, an excellent site was purchased, and Mr. William Fawcett, M.A., of Cambridge, brother of the present Postmaster-General, prepared designs, which were approved by the Science and Art Department.

Unfortunately, before the scheme was fairly launched the good times passed away and were rapidly followed by an unparalleled period of adversity in the coal trade. It was felt that the needful funds could not be obtained until money was more abundant, and the committee wisely determined to wait for better times. But still the school was having a prosperous career, in numbers and in successes. And during last summer vacation (1882) the committee decided to put to some useful purpose the valuable piece of land which they had bought in the heart of the town and adjoining the Free Public Library, and to expend two thousand pounds in raising and furnishing temporary buildings. These buildings have been erected by Messrs. Francis Morton and Co., of Liverpool, and were ready for occupation at the beginning of the present year. They comprise one large lecture hall, which provides accommodation, if need be, for 100 students in drawing, and will accommodate a meeting of 400 persons. There is a smaller lecture hall with ample space for a meeting of 100; a chemical laboratory intended to be fitted for 24 students in practical chemistry; two lecturers' private rooms; a cloak room; a model room; and two front entrances with commodious porch to each. There are the usual lavatory arrangements, and the whole of the rooms are heated with hot water.

These rooms are chiefly used by the classes in the evening, and during the day occasional meetings of the Manchester Geological Society and the Lancashire and Cheshire Permanent Relief Society are held. During each summer recess an exhibition will be organised, and the first will be an Exhibition of Gas Appliances this summer, 1883, under the auspices of the Wigan Corporation.

But the Committee distinctly state that the present erection is only temporary, and must be considered as such. At a recent public distribution of prizes, Mr. Alfred Hewlett said the supporters had put their hands to the plough, and would not turn back. They were determined that the Wigan Mining and Mechanical School should have a permanent structure worthy of its work in the past and its still greater aims in the future.

The regular work of the school during the 25th session which commenced September, 1882, and will end May 31st, 1883, has comprised classes under the Science and Art Department in Mining, Geology, the Steam Engine, Chemistry, Magnetism, and Electricity, Acoustics, Light and Heat, Mechanical Drawing, Building Construction, and Applied Mechanics. Also classes under the City and Guilds of London Institute for the Advancement of Technical Education in Mechanical Engineering, and Iron and Steel Manufacture. The general ticket of the school, issued at ten shillings, admits to any or all of these classes during the whole of the session, and the syllabus in each subject is laid down by the London authorities, who hold examinations in May.

In addition to the prizes and certificates which are open to this school in common with similar institutions in the United Kingdom, special awards are made. Mr. Thomas Knowles, M.P., provides annually a gold medal, and the Committee provide a silver medal; the Rev. Canon Fergie gives a valuable prize in books to the most successful student, who must be a working miner, and Mrs. Peace presents a special prize, as also do various Members of the Committee.

A few years ago a new section was established for the special instruction of persons intending to compete for Certificates of Competency as Mine Managers, and two terms are held in each session, namely, from September to December, for the Manchester examination, and from March to June for the Wigan examination. The fee for each term is two guineas, and a special syllabus has been prepared for this section. From this section students have gone out to become inspectors of mines, and to hold valuable engineering appointments all over the world.

About once in each month an afternoon visit is made to some colliery or iron works, or steel works, or other engineering industry, comprising sometimes a few and at other times a large body of students, and the various operations are explained by the proprietors and their officials. These visits have for several years been an important feature in the programme of instruction, and the Science and Art Department, and the City and Guilds of London Institute very properly recognise these visits as attendances of the class or classes.

During the session now ending such visits have been made and organised to the under-mentioned collieries and works:—Messrs. the Moss Hall Coal Company, Rose Bridge and Douglas Bank Coal Company, Woods & Son, the Abram Coal Company, the Brinsop Hall Coal Company, the Astley and Tyldesley Coal Company, the Wigan Coal

and Iron Company, and the London and North-Western Railway Company's Steel Works at Crewe.

Such is a sketch of the Wigan Mining and Mechanical School, which has had an existence of a quarter of a century, and which, during that period, has not changed its chairman, Rev. Canon Fergie, B.D., nor its honorary secretary, Mr. Maskell W. Peace, F.G.S., and which has upon its committee and amongst its supporters all the leading employers of labour in and around Wigan.

NOTE A. (See page 6.) *Putting to and filling from Stock.*—An equally effective and more compact means of raising fuel out of stock on to the pit bank for screening and loading into wagons has been introduced in the shape of vertical steam or hydraulic hoists. These can be placed anywhere, occupy less space than engines fixed on pit banks drawing up inclines, enable the stock to be filled up with less waste, are not more expensive, and give a larger useful effect. The amount of coals put to stock will depend on the variations of trade, and also the nature of the coal. Some classes fall to such an extent when exposed to the atmosphere that stocking is a ruinous process. On the other hand, with coals that will stand well, and where, such as with cannel or gas coal, the demand is scarcely anything in the summer, and very great in the winter, it is a convenience to have accommodation for stocking a few weeks' output.

NOTE B. (See page 9.) *Geared Engines for Winding.*—The great danger in geared engines, as has already been mentioned, is that they will break. The spur wheels are usually all of cast-iron, which, always to some extent a brittle substance, becomes more so as years go on. The work is not regular, and consequently the teeth are constantly clashing and clanging, the brittleness increases, and some day the wheels break. A geared engine had been in use for twenty years as a winding engine; some men were being drawn up in a hoppitt after making repairs; the hoppitt caught under a horse-tree, and brought the machinery to a sudden stand. The severe shock broke the spur wheels, and the hoppitt ran back with disastrous results. A single engine may do well enough for winding if there be simply two stopping and starting places—namely, one at the top and the other at the bottom. But in any shaft inspection and repairs may be needed at any point, necessitating the most easy movement of the engine. With a single engine this is practically impossible.

NOTE C_1. (See page 16.) *Mixtures of Iron for Cylinders.*—Mr. Arthur Rigg, in his treatise on the steam engine, recommends as a very good mixture for strong and close-grained iron for steam cylinders, 8 parts by weight of No. 5 charcoal pig, 10 parts Scotch pig, and 10 parts scrap iron. Another mixture is made of Blaenavon cold blast, Silverdale Madeley Wood hæmatite No. 7 or 8, and Glengarnock mixed with good scrap in varying proportions. Two parts No. 5 charcoal pig, 4 parts Scotch pig, and 30 parts scrap form an excellent metal where great hardness is required. The addition of 2 or 3 per cent. of manganese to cast-iron has been found advantageous in producing a good, hard, and slippery surface for cylinders, slide valves, and motion bars. And such a mixture of metal is obtainable by proportions of North Lincolnshire manganiferous iron with hæmatite and a little Scotch

pig, for the purpose of securing fluidity. Such metal can be turned and bored without difficulty, but will not easily file or wear. Mr. Daniel Adamson says that to obtain a metal possessing the utmost slipperiness of surface manganiferous iron must be used. For heavy castings where great tensile strength was required, spiegeleisen should not be used, but to produce an iron good for turning and boring, a manganiferous iron must be used. He had for years adopted a mixture of North Lincolnshire manganiferous iron with hæmatite and a little Scotch pig. Such a mixture gave a close metal which, while difficult to file, could be turned and bored with great facility.

NOTE C_2. (See page 21.) *Back Piston Rods.*—In a paper on Direct Acting Winding Engines, read by Mr. G. Daglish, at Manchester, in 1875, he said:—"In 1870 more power was required for winding at Rose Bridge Collieries, and it was considered desirable not to increase the pressure of steam. The back piston rods were taken away, and the result has been that 4 to 5 pounds per square inch pressure of steam has been saved, and the piston rings, which are of cast-iron, last eighteen months. The cylinders, which are 36 inches diameter, have never been bored since they were erected, and the repairs have been less since the back piston rods were removed. The maximum piston speed is 700 feet per minute, and this severe test answers all the objections made to the abandonment of back piston rods." Mr. Jeremiah Head mentioned that he had some large engines at work with back piston rods, and thought the plan worse than useless. During the discussion, Mr. Reynolds, Mr. Rye, Mr. Davey, Mr. Adamson, and Mr. Bramwell all agreed that back piston rods might very well be dispensed with.

NOTE C_3. (See page 23.) *Friction of Slide Valves.*—Mr. W. G. Beattie, in introducing a balanced slide valve in 1870, gave the result of some experiments with the ordinary slide valve as applied to locomotives. The total resistances offered by the valve and the eccentric straps amounted to a force of 1,085 lbs. at the piston, and the piston being 17 in. diameter, this was a constant deduction of 5 lbs. per square inch from the effective pressure of steam upon the piston, or a loss of about 8 per cent. of the effective power of the engine.

NOTE D_1. (See page 35.) *Winding Engine-houses.*—In some engine-houses very complete arrangements are made for lifting. For example, at the Barnsley collieries of the Barrow Hæmatite Co. travelling cranes are fixed in each engine-house spanning the entire width and running the whole length. These cranes have nearly paid for themselves in the lessened expense of erecting the engines in the first instance, and by means of them repairs of an extensive character can, if necessary, be effected with fewer men and in less time than would be the case without them.

NOTE D_2. (See page 40.) *The Kœpe System.*—As arranged at Bestwood, this system is more elaborate than has been described in Chapter IV. True, there is only one winding rope, but there are two lighter or safety ropes also attached to both cages, and the object of these is that should the main rope break, the cages will not run down the pit. The manner of their operation is somewhat curious. The ends are attached to the respective cages, and the ropes pass over two pulleys in the head-gear. The diameter of these pulleys is the distance from centre to centre of cages. So long as the main rope does not break, these safety ropes simply move about, but when the main rope breaks, the safety ropes have the weight thrown upon them, and pressing down upon their pulleys are brought to a stand and

prevent either cage running back. This arrangement necessitates, in addition to the main winding rope, two safety ropes, and a balance rope under the cages equal in weight to the other three. It is really no part of the Kœpe system, introduces complication, and is not necessary. The Kœpe system proper consists, as described, of one winding rope, one balance rope and one drum pulley.

NOTE E. (See page 45.) *Friction on Ropes.*—As a contrast to the arrangement of Pearson and Knowles, where the drum is 30 yards from pulley and the ropes do well, there are other collieries where the results are quite different. There is one important colliery at which the cage and tubs and fuel weigh 6 tons and the rope weighs 3 tons. The distance from drum to pulley, although the pit is deep and drum cylindrical, does not exceed 20 yards. The result is short lives for ropes, and they fail first at cage end namely, where the load is least, on account of the enormous amount of side, friction. This simple defect has cost the owners thousands of pounds.

NOTE F. (See page 50.) *Speed of Winding Engines.*—The difference in speed between condensing and non-condensing engines is shown by taking two well-known examples, namely, Rose Bridge and Monkwearmouth. At Rose Bridge a winding of 800 yards is made in 50 seconds, being an average speed of rope = 960 yards per minute. At Monkwearmouth the winding of 600 yards occupies 1½ minutes, being an average speed for rope of only 400 yards per minute.

NOTE G_1. (See page 51.) *The Bickershaw Collieries.*—Bickershaw may appear quite a new name to some readers, and they may be surprised to hear of so important a colliery at so apparently unimportant a place in the colliery world; but Bickershaw in the future will be, if not the centre, at any rate an important portion of the Lancashire coalfield. There are already in it, and close round it, several important collieries with large and increasing outputs, and as several of the older Wigan collieries are getting worse for wear, and passing out of existence, their falling off will be more than counterbalanced by the development of the extensive seams in and about Bickershaw.

NOTE G_2 (See page 55.) *Defective Brakes.*—It would be more correct to say that no fatal accident resulted, because on one occasion men were being lowered and the hoppitt ran away. No person was killed, but the dashing of the hoppitt against the bottom of the shaft did hurt somewhat seriously several of the men who were descending. This mishap occurred at midnight, on resuming work after half-an-hour's interval for supper, and there has always been some suspicion on the writer's mind that the engineman had been enjoying a portion of his half-hour's rest in sleep, and was not as wide awake as he should have been when work was resumed. In sinking shafts, an operation, attended with a good deal of danger and consequently demanding constant care on the part of all concerned, the safe plan would seem to be shorter shifts without any intervals for meals. Then no one has any excuse for going to sleep.

NOTE H_1. (See page 56.) *Manufacture of Ropes.*—In 1862 Mr. C. P. B. Shelley, now Professor of Manufacturing Art at King's College, read a paper on the manufacture of hemp and wire ropes, and now published in the *Transactions* of the Institute of Mechanical Engineers for that year. During the discussion an interesting comparison was drawn between hemp and wire An iron wire rope $\frac{1}{10}$ in. diameter had been tested and it bore 18½ tons before

breaking, and calculating the quantity of wire in the rope this showed a strength equal to 50 tons per square inch. It was remarked that a hemp rope to bear the same load would require to be rather more than 2½ in. diameter, and would be about twice as heavy as the iron wire rope. The chairman of the meeting gave an eminent ropemaker who furnished this information a cordial invitation to give the results of his experiments on the strength of wire ropes in the form of a paper. But although twenty years have come and gone since then the invitation has never been accepted. It still remains for some one to step into the breach and give information as to material and manufacture of wire ropes, iron and steel of various qualities.

NOTE H_2. (See page 68.) *Vertical Drums.*—The writer whilst designing some colliery machinery for a colliery at which it had been decided that winding ropes should be used, appreciating the difficulty of a deep pit, and with a large number of coils, of causing the ropes to coil truly, prepared some rather elaborate drawings of a cast-iron vertical drum dispensing with arms altogether, and having proper cast-iron flanges all round the drum and as deep as under ordinary circumstances the arms would be, and thought something new had been introduced to the notice of the mining world, but was somewhat taken aback on making a tour of the South Wales coalfield shortly afterwards and finding the very thing an old appliance at several Welsh collieries. Verily history repeats itself even in mining.

NOTE H_3. (See page 70.) *Indicator to Record Number of Windings.*—On at least one pair of winding engines at the Hetton Collieries there is such an indicator, which records each complete winding that the engines make, and whilst recording the work with accuracy is no trouble, and seems to have no liability to get out of order.

NOTE I_1. (See page 78.) *Clearance below Conductor Weights.*—Some anonymous correspondent, but no doubt well-intentioned friend, when these articles were passing through the *Colliery Guardian*, took exception to this clearance of two yards, or rather assumed that it was a misprint, and should have read two inches. Of course two feet, and even two inches of clearance under weights is just as good as two miles if we can depend upon it. But the writer's experience is that wire conductors get longer, and dirt accumulates in the sump. Taking into consideration these two facts, two yards are not much for clearance under the conductor weights.

NOTE I_2. (See page 82.) *Catches under Cages.*—The writer is strongly of opinion that wherever possible the catches usually placed under cages should be dispensed with. When vertical or spiral drums are part of the colliery appliances this is not easy, but with cylindrical drums there is no difficulty. There are no such catches used at the important collieries of Bridgewater, Clifton and Kersley, and Burnley. The result is, time is saved in banking, ropes and cappings last longer, and the cages without needing to be so strongly made, receive less injury and consequently require fewer repairs.

NOTE I_3. (See page 85.) *Engineman's Presence of Mind.*—It is pleasing to have an opportunity of saying a word in favour of so excellent a class of men as winding enginemen. Their occupation requires no great amount of skill, but an engineman should not be a mere automaton. Upon their care, all our safety appliances notwithstanding, depend the lives of every person descending a mine twice in each day, and upon their expertness depends the output. They are often at night the only persons engaged about the surface,

and the writer remembers very well on one occasion the wood work of pumps in a furnace shaft got on fire, and but for the presence of mind of the engineman in first turning all the pump water into the burning shaft and then getting assistance, the results would have been very serious.

NOTE J. (See page 93.) *Apparatus for the Prevention of Overwinding.*—There need be no concealment as to the special appliance that was referred to, namely, the patent of Charles Ianson, Son, and Co., of Darlington, and entitled "Apparatus for the Prevention of Overwinding," because the arrangement is ingenious enough and its working out most creditable. The principle and operation are as follows:—Immediately the cage rises beyond the point at which it ought to be stopped it comes in contact with a lever which releases a lock, and by a simple contrivance at once cuts the steam off the engine and allows it to pass into the steam brake cylinder, thus applying a powerful brake and at once arresting the motion of the engine. At the same time the steam contained in the cylinders is released, thus avoiding any tendency to continued motion of the engine after the brake is applied, due to the exhaustion of the steam. Should the engine be started in the wrong direction, it is at once stopped by the cage striking the lever, and releasing the lock, which allows the steam to get access to the brake cylinder, so that it cannot possibly travel far enough for any harm to result. When the apparatus comes into action, the cage remains suspended at the point to which it has travelled until the steam is turned off at the boilers and let out of the steam brake cylinder, by opening a cock provided for that purpose, by which means it can be let down on the keps quietly and gradually. All that is then needed is to replace the lock, and until this is done the engine cannot be started, thus ensuring the lock always being in the proper position when the engine is working. The lever can be placed at any height, so as to give the cage any range in working that may be desired. The brake employed can either be the existing foot brake, to which the steam cylinder can be attached, or preferably an additional and separate brake, leaving the existing brake uninterfered with; or it may be arranged so that the steam brake can he utilised in the ordinary working of the shaft, yet without destroying the self-acting character of the apparatus.

NOTE K_1. (See page 100.) *Tipplers.*—A considerable correspondence arose immediately after mention was made of the tippler specially described in Chapter XI., and Messrs. Mowle, Son, and Co., of Chester, kindly sent particulars of one which they have made with great success, and which they thought was the kind of tippler described. Messrs. Mowle and Co.'s tippler receives the tub at the side, and can be so made as to allow the loaded tub to enter at one side, and the empty tub leave at the other side. The writer has not been fortunate enough to see such an arrangement at work, the side tipplers with which he has had experience having one side closed. That described and illustrated in Chapter XI., has been in very general use many years and gives satisfaction wherever applied.

NOTE K_2. (See page 104.) *Accidents about Screens.*—The number of accidents happening about screens is at many collieries very considerable, owing to want of care on the part of the unfortunates themselves. A very common class of accident is being crushed between buffers and that only care on the part of the workpeople having to do with wagons can prevent. Another is the getting crushed between a wagon and an upright. Usually the wagon is being brought in under the screen and the person kneeling on the brake has his back to the post, with which he, before he is aware, finds

himself in contact, and is either killed or badly injured. All uprights about screens should be placed so as to allow ample clearance.

NOTE L_1. (See page 106.) *Tipping and Screening.*—Usually at collieries the tubs have no separate numbers, but all tubs sent by one collier or several colliers working in company carry a tally which bears the collier or colliers' number. And no record is kept of what tubs go down certain screens into certain wagons. So that although a particular tub may be detected as to its dirtiness during tipping or whilst being weighed no record is kept of where it goes. At Clay Cross the screens are numbered, the tubs are numbered, and the wagons are of course numbered. A boy placed at each screen keeps a record of the numbers of all tubs passing down his screen into certain wagons, which record gives the numbers of the colliers who sent the fuel, the tubs it came in, the screen down which it passed, and the wagons loaded with it, thus affording a check upon the colliers below and the screeners and pickers above.

NOTE L_2. (See page 110.) *Expense of Efficient Screens.*—An objection raised by many colliery proprietors against Rigg's appliances is not as regards their efficiency but takes exception to their cost. Any appliances which deal thoroughly with the screening and tipping of fuel will be expensive as compared with fixed screens. An expenditure of £1,000 would probably equip a colliery dealing with 700 tons per day and even on the supposition that all this was extra cost (which it is not, because fixed screens cost something) increasing the market value twopence per ton would more than wipe off the cost in one year. And really this is the right way to look at it, because extra capital is well expended if it produces a good return.

NOTE M. (See page 117.) *Testing Boilers.*—There is no very satisfactory test for boilers, because we can hardly get steam up and run the risk of accident to boiler itself and danger to human life, and a test with cold and sluggish water scarcely shows the action of working with hot and elastic steam. Some authorities urge that to put a strain upon a boiler double that at which it has to work is an absolute injury. Nothing less than twice the hydraulic pressure of the intended steam pressure will be satisfactory and there really can be no injury, because the ultimate strength should never be less than four times, and is often six times greater than the maximum working pressure. Boilers under test should be carefully observed as to leakages and distortions.

NOTE N_1. (See page 120.) *The Exhaust Injector.*—This appliance was introduced to public notice about the end of 1880, but private tests made two years previously had been so satisfactory that several had been in action before the public were made acquainted with it. The first application to stationary engines was at the Ocean Collieries, Glamorgan, of Messrs. David Davies and Co., in 1879, on winding, hauling, and constant running engines. The first application to locomotives was in 1878, on one of the Welsh railways. There are in 1882 some 700 in use, largely applied to ordinary stationary non-condensing engines at ironworks, collieries, etc. Smaller sizes are used for saw mills, brickworks, warehouses, and electric light engines. The length of time some of them have been in regular work has shown their non-liability to get out of repair. What these injectors actually accomplish is, they take the exhaust steam from the engine and with no other power feed the boilers. If they take the place of pump arrangements that have

been feeding with cold water they at once effect a saving of 25 per cent. in fuel consumed. If hot feed water has been used previously then the saving is that no fresh steam is required as motive power to feed the boilers. Then as regards the economy of water, which in some cases is as important as saving fuel. Experiments were made with a No. 12 injector; taking water at 68 degs., delivered water in the boiler at 168 degs., and drawing from feed water tank 2,490 gallons per hour, delivered into the boiler 2,736 gallons, showing weight of water due to and saved by exhaust steam 246 gallons per hour. Another experiment with same number of injector, namely, 12, took feed water at 68 degs., and delivered it at 190 degs., and drawing 2,280 gallons of water per hour from the feed water tank, delivered into the boiler 2,561 gallons making the water due to and saved by exhaust steam 281 gallons per hour. The exhaust injector practically works at any pressure, however high, as shown by its application to locomotives, and can work and has worked with less than no ordinary pressure. That is with exhaust steam below atmospheric pressure, feed water has been forced into a boiler working at 60 pounds. A special chapter will be devoted to describing and illustrating this appliance in the second volume.

NOTE N_2. (See page 124.) *Course of Draught in Boilers.*—Mr. Pole, in his work on the Cornish Pumping Engine, argues that the heated current first, on the top of the tube where the highest and therefore the hottest portion of the water is lying, should then pass along the side flues, where it finds the surfaces cooler than before, and last of all traverse under the bottom of the boiler, where the coldest water will always be. By this means the fire current, as it gradually cools, is likewise brought to act upon cooler water, and thereby the best opportunity is afforded for the extraction of the heat. Mr. Pole's arrangement is not generally adopted. It is contended that allowing the last heat to travel under the bottom of the shell does not promote the circulation of the water, or at all events but slowly, so that in getting up steam the top of the boiler becomes hotter than the bottom, from which straining ensues. In the Lancashire boiler, in consequence of seam rents occurring at the bottom when the last heat is carried underneath, the plan of passing the flame under the bottom immediately on leaving the furnace tubes has become the general practice.

NOTE N_3. (See page 125.) *Feed Pipes in Boilers.*—It has been mentioned that feed water should be sent into boilers through small perforations in the internal feed pipes, which perforations, although not troublesome with good water, are liable with impure water to make up, and if so, inconvenience, not to mention danger, arises. These perforations should be examined each time the boiler is cleaned—namely, once a month, and if the attendant is not afraid of a small shower bath, the feed should be turned on just after he has finished cleaning and before leaving the boiler.

NOTE O_1. (See page 141.) *Injury to Boilers by Ashes.*—In the primitive days it was thought anything would do for covering boilers to prevent condensation; but in this respect much more care is now exercised, and wherever good boilers are used they are carefully covered with some non-injurious substance which is a good non-conductor. Such covering is also in most cases supplemented with brickwork. But the practice prevailing of drawing out ashes from the flues of Lancashire or Cornish boilers, letting them lie against the front of boiler and watering them there, and then allowing them to lie until quite cool is most barbarous, and a boiler which with fair wear and tear would work a dozen years requires partial renewal

at the front in as many months. There is no difficulty in drawing the ashes from the flues into barrows and thus never allowing contact with boiler-plates at all, and certainly not whilst being watered and cooling down afterwards.

NOTE O_2. (See page 143.) *The Manchester Steam Users' Association.*—The many Boiler Insurance Companies established in various parts of the country for inspection and insurance have produced good results, as shown in the lessened number of explosions. The Manchester Steam Users, without working on the lines of insurance, have been exceedingly effective in inducing boiler owners to have good boilers when new and keep them in good repair. They comprise the principal owners of works for very many miles round Manchester, and have in their service a small regiment of engineers skilful in examining and making reports. These examinations and reports are at the command of their members, and provided certain conditions as to structure of boilers are fulfilled a guarantee to a certain amount is given.

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